U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Filing Code 9220
Date Issued May 1980
Technical Note # 341

TECHNICAL NOTE

U.S. DEPARTMENT OF THE INTERIOR – BUREAU OF LAND MANAGEMENT

EFFECTS OF MESQUITE SPRAYING ON OTHER RANGELAND RESOURCES

R. E. Sosebee and B. E. Dahl

Department of Range and Wildlife Management
Texas Tech University
Lubbock, Texas 79409

Final Report, submitted to the Bureau of Land Management, Santa Fe, New Mexico

March 25, 1979

Additional copies of Technical Notes are available from DSC, Federal Center Building 50, Denver, Colo., 80225

PREFACE

Since 1969, there has been a great deal of controversy about the use of herbicides to control noxious brush and weeds. Much of the furor has revolved around the use of phenoxy herbicides, specifically 2,4,5-Trichlorophenoxyacetic acid (2,4,5-T), and the impurity 2,3,7,8-Tetrachloro-dibenzo-p-dioxin (TCDD, "dioxin"). The general American public's concept of herbicide useage is related to the use of "Agent Orange" in southeast Asia during the Viet Nam conflict. Agent Orange is similar in name only to the phenoxy herbicides used in this country and should not be construed as being similar to the 2,4,5-T sold and used in the United States.

Emotionalism has dictated our decisions in recent years regarding the useage of any pesticides (insecticide, herbicide, fungicide, etc.) as a result of Rachael Carson's book entitled Silent Spring (published in 1962). Ms. Carson brought to the awareness of the American people the dangers associated with abuse, and perhaps use, of pesticides. However, the American public was not scientifically prepared to either accept or reject her book at the time it was published.

Much research has been conducted to evaluate the effectiveness of various herbicides in controlling noxious plants and the longevity of treatments. Recently, there have been many studies conducted to determine the effect of herbicide on non-target organisms and its relationship to non-point source pollution. Aside from much, if not most, of the research, a great deal of information has been circulated via the news media relating public attitude and sentiment toward the use of pesticides.

The authors gratefully acknowledge support from the Bureau of Land Management, U.S. Department of Interior (Contract No. NM-910-CT8-10) for whom

TABLE OF CONTENTS

Page

I. Effectiveness of Controlling Mesquite
- A. Successful Herbicides. I-1
- B. Methods and Timing of Application. I-38

II. Effects on Related Resources
- A. Watershed Vales
  - 1. Soil Erosion I-74
  - 2. Particulate matter (dust) in atmosphere. I-75
  - 3. Soil, water and air contamination. I-76
- B. Vegetative Composition I-100
- C. Wildlife Habitat
  - 1. Antelope and other big game. I-118
  - 2. Upland game birds. I-134
  - 3. Birds of prey. I-149
  - 4. Other birds. I-150
  - 5. Predators. I-152
  - 6. Rodents. I-156
  - 7. Reptiles I-158
  - 8. Fish I-162
  - 9. Amphibians I-163
- D. Livestock Forage Production. I-164
- E. Visual and Aesthetic Values. I-214

III. Pollution and Toxic Hazards
- A. Toxicity
  - 1. Humans I-218
  - 2. Mammals. I-231
  - 3. Birds. I-275
  - 4. Reptiles I-288
  - 5. Fish I-290
  - 6. Food Chain I-306
  - 7. Other. I-320
- B. Mobility and Degradation Rate. I-338

IV. Alternative Methods of Control
- A. Effectiveness. I-361
- B. Economic Feasibility I-383

this anotated bibliography was prepared. As the title, "Effects of Mesquite Spraying on Other Rangeland Resources," indicates this report was designed to be a comprehensive review of the literature pertaining to the pertinent scientific research on the effect of all herbicides used in spraying mesquite (Prosopis sp.). The effects reported herein include successful herbicides as well as those that might have potential in the near future. Methods and timing of application are particularly important in achieving maximum control with the least amount of effect on other resources. Effects on other resources such as watershed values, associated vegetative composition, wildlife habitat, livestock forage production and aesthetic values of spraying are also reported.

A significant portion of the report is related to the pollution and toxic hazards of herbicides used to spray mesquite. Toxic effects on humans, other mammals, birds, reptiles, fish and insects are presented. Although not much information is available on the effects of herbicides (used in spraying mesquite) on the food chain, information that is available is included. A section of this report is also devoted to the mobility of degradation rates of herbicides used to spray mesquite.

The report is concluded by discussing the effectiveness and economic feasibility of alternative methods of mesquite control. However, very little information is available in the literature on economic feasibility of alternative methods.

Hopefully, information contained in this report will enable its readers to assess the impact of spraying mesquite on the environment and make their decision based on scientific evidence and not on emotional infatuations.

I. Effectivenss of Controlling Mesquite

A. Successful Herbicides

Streets, R. B. and E. B. Stanley. 1938. Control of mesquite and noxious shrubs on southern Arizona grassland ranges, p. 469-497. In, Tech. Bull. No. 74. Univ. of Arizona. Tucson, Arizona. (Plant pathologist and Animal Husbandman, Ariz. Agr. Exp. Sta.; research conducted in southern Arizona).

The spread of mesquite into rangelands of the Southwest to the detriment of the grazing capacity of the land invaded has become a problem of considerable importance to cattlemen in certain districts in Arizona and Texas.

In Arizona the velvet mesquite has spread from the watercourses, to which it was largely limited some 60 years ago, up into secondary channels and ravines and out over the means reducing the carrying capacity of some of the best grassland cattle ranges in southeastern Arizona.

The spread of mesquite appears to be chiefly due to the hard seeds, many of which survive mastication and digestion when the mesquite beans are browsed freely by livestock.

Cutting alone has not proved successful in controlling mesquite, as the stumps promptly sprout forming dense clumps more objectionable than the original tree.

This bulletin reports the results of experiments with 27 different methods of mesquite control under range conditions. Among the materials tested were: sodium arsenite, white arsenic, acid-arsenic and sulphuric-acid sprays, petroleum oils, sodium thiocyanate, and ammonium sulphide. These materials were applied as sprays or in cuts or holes or the base of the trunk. Torching was likewise tried.

One method, which has been further proved by testing on a larger scale, is recommended for the control or eradication of mesquite in grassland ranges. This method, which is 100% effective when carefully used, is to apply sodium arsenite to the sapwood by frilling the base of stump or tree with downward strokes of an axe. The poison is rapidly absorbed by the root system in quantities sufficient to kill it.

Streets and Stanley 1938 (con't.)

An experiment where sufficient mesquite was cut to produce 50 cords of wood gave the following cost data for poisoning of stumps: poison, 10 cents per cord; labor, 10 cents per cord. Two men with axes and one of them applying poison treated stumps yielded 30 cords of wood in one day. The sodium arsenite treatment is cheaper, more certain to kill than the other methods tested, and is about equally effective any month of the year.

Application of kerosene to the lower part of the trunk has in some cases proved very effective where proper dosage, method of application and time of application are observed. Spraying the trunk to a height of 2 ft, holding nozzle close to saturate bark, and applying kerosene at the rate of 1 pint to a 5-inch trunk is recommended. June is the best month for applying kerosene in Arizona, and May or April second best. The action of kerosene is much slower than that of sodium arsenite, and it cannot be recommended without reservation until more experience under Arizona conditions is available.

None of the other methods of killing mesquite tested is considered to be suitable from the standpoint of effectiveness, economy, and ease of application for general use on cattle ranges.

Control of mesquite on grassland ranges rather than its eradication is suggested on account of its value as spring forage.

The sodium-arsenite method is adapted to and has proved successful for the killing of unwanted trees in city and country yards and along fence rows and ditches.

Burroweed (*Aplopappus fruticosus*) and snakeweed (*Xanthocephalum sarothrae*), two unpalatable perennial shrubs which are also more or less poisonous to livestock, are likewise spreading into the better grassland ranges, causing concern among cattlemen.

Preliminary experiments on methods of controlling these shrubs by means of spraying, grubbing, and burning indicate that these xerophytic plants are unusually resistant to sprays; that grubbing is effective but impractical where plants or seedlings are abundant; and that torching of scattered plants or careful broadcast burning of patches is the most effective control now known.

Snakeweed was observed to be partially controlled but not eradicated by two insect enemies and severe drought and seedlings of burroweed were found to die in drought period.

It should be emphasized that the expense and labor of eradication of mesquite, burroweed, snakeweed or other undesirable plants is justified only on grassland ranges where it is quite certain that palatable grasses and forage plants will take their places. The problem of rehabilitating deteriorated desert ranges must be solved by further experimental work.

Fisher, C. E. 1942. Mesquite eradication studies at Spur, Texas. The Cattleman 28:34-35, 37. (Asst. Soil Conservationist, Texas Agr. Exp. Sta.; research conducted at Spur, Texas).

Asbaugh, F. A. and K. C. Barrons. 1946. Cost of right-of-way vegetation control cut 50% by new chemical. Electric Light and Power 24(11): 56-58, 60. (Credentials unknown).

Results of 2 years use are described with a list of 38 woody plants destroyed. The solution used contained one part of Esteron (containing 44% of the isopropyl ester of 2,4-D acid) and 99 parts kerosene. The spraying is more effective if it is carried out at a time when the plants are in a growing phase.

Fisher, C. E., J. L. Fults, and H. Hopp. 1946. Factors affecting action of oils and water-soluble chemicals in mesquite eradication. Ecol. Monogr. 16:109-126. (Agronomist, Assoc. Agronomist, and Soil Conserv., respectively, Texas Agr. Exp. Sta., Spur, Texas; research conducted at Amarillo and Spur, Texas).

Studies of some of the factors affecting the action of water-soluble chemicals and oils in eradication of mesquite were made between 1939 and 1945 in Amarillo and Spur, Texas.

Morphological studies showed that the dormant buds on the underground stems of mesquite, a sprouting shrub, must be destroyed in order to kill the plant.

Factors affecting the action of water-soluble chemicals and oils in reaching the dormant buds on the underground stems were studied on individual trees, small plots, and field-size areas.

All materials tested were either systemic or local. Water-soluble substances, such as sodium arsenite were systemic chemicals, while the substances insoluble in water, like kerosene, functioned as local poisons.

The movement of sodium arsenite takes place through the vascular system longitudinally with little or no tangential movement. Downward movement is restricted by the presence of living tissues in forked stems and also by areas of dead tissue between the point of application

Fisher et al. 1946 (con't.)

and the critical zone of dormant buds. The extent of penetration of sodium arsenite in plant tissue is directly related to the length of time it remains in moist contact with the sapwood.

A concentration of at least the equivalent of 4 lb of $A_{s2}O_3$/gal, applied as sodium arsenite to the sapwood of the root crown was necessary to obtain sufficient penetration to give consistently a high percentage of kill.

Equally effective results can be obtained during all seasons of the year when the sapwood is properly prepared.

The selection of a method of applying sodium arsenite to sapwood to obtain successful kills should be made on the basis of the growth form of the mesquite.

Kerosene is a contact poison that must be placed directly in physical contact with the critical bud zone to kill mesquite. It does not move in the vascular system except by gravity action.

The volume of kerosene necessary to kill mesquite depends on method of application, growth form, and the soil factors of texture and moisture content.

Seasonal treatment with kerosene shows that moisture content in the upper foot of soil is probably of more importance than any physiological change within the plant. In general, the most successful kills were obtained during the summer when the surface soil was dry.

Successful kills with kerosene were obtained on single to few-stemmed trees on porous soils with an average of 1 quart/tree. On heavy soils with many-stemmed mesquite, 2 quarts of kerosene per tree were necessary to give effective kills.

Of the many water-soluble chemicals tested, none has been found that is more effective and economical than sodium arsenite. Kerosene, diesel fuel, and other petroleum oils were equal to their effectiveness and the choice among them depends on cost and availability. The addition of oil soluble chemicals did not increase toxicity or percentage of kill.

Caird, R. W. 1947. Eradicating mesquite. The Cattleman 23(8):23-26, 85.

(Credentials unknown).

Eradication and control of mesquite is necessary for efficient and profitable use of the land. Two effective ways of eradicating mesquite are mechanical and chemical. Survey is made of the different ways of mechanical control: root cutters, dozers, mowers, rakes, etc. Chemical control such as the use of kerosene, is cheaper than

Caird 1947 (con't.)

mechanical means and just as effective. Combination of the two methods may be the answer to some brush clearance.

Elwell, H. M. 1947. Chemicals for brush control. Oklahoma Agr. Exp. Sta. Mimeogr. Cir. No. 164. 6p. (Credentials unknown).

One application of 2,4-D at 2000 ppm gave 80 to 95% defoliation of sumac (*Rhus glabra*), sand plum (*Prunus angustifolia*), black locust (*Robinia pseudoacacia*), honey locust (*Gledilsia triaconthos*), persimmon (*Diospyros virginiana*), and sassafras (*Sassafras variforium*); 50 to 75% defoliation of blackjack oak (*Quercus marilandica*), post oak (*Quercus stellata*), dwarf chinquapin oak (*Quercus muhlenbergii*), and willow (*Salix nigra*); and no defoliation of American elm (*Ulmus americana*), winged elm (*Ulmus alata*), mesquite (*Prosopis juliflora glandulosa*), hackberry (*Celtis occidentalis crassifolia*), hickory (*Hicoria buckleyi*), Bois D'are (*Toxylon pomiferum*), and red cedar (*Juniperus virginiana*). Dow's A 510, DuPont's 2,4-D, Weedone, Weedno-more, Dow's liquid 2,4-D, and Tufor-40 defoliated from 19.1 to 91.7% of blackjack, white and chinquapin oakbrush at various locations in the state. Ammate (ammonium sulfamate) applied to these oaks defoliated from 40 to 99.0%. When trees were completely girdled with an axe near the ground, and undiluted Weedone, Esteron, a saturated solution of Dow's A 510, DuPont's 2,4-D, Ammate, and sodium arsenite were applied individually in the incisions, sodium arsenite was the only chemical which killed large trees. Ammate was effective on small trees. 2,4-D compositions were ineffective. The compositions were not effective when applied in holes punched in trees.

Lancaster, R. R. 1948. Killing trées and shrubs with kerosene and sodium arsenite. Texas A&M Univ. Ext. Leaflet No. 59. (Credentials unknown).

Mesquite control with kerosene and sodium arsenite is effective under proper application. Various tests are described and means of use of these chemicals are given.

Burley, R. 1949. Specialists fight brush with 2,4,5-T. Western Livestock 34(11):37. (Credentials unknown).

Very brief note on the use of 2,4,5-T for controlling brush. Under certain conditions and careful application, the chemical is quite useful in combating brush.

Elder, W. C., H. M. Elwell, and F. A. Romshe. 1949. Chemical control of weeds and brush in Oklahoma. Oklahoma Agr. Exp. Sta. Bull. No. 335. 26p. (Elder and Romshe, respectively, Asst. Agron. and Assoc. Hortic., Okla. Agr. Exp. Sta., Elwell - Soil Conserv., Red Plains Cons. Exp. Sta., Guthrie, Oklahoma; research conducted in Oklahoma).

A review of various chemical herbicides and their effect in controlling oak, hickory, persimmon, and similar types of brush. 2,4-D, 2,4,5-T acid and ammate are some of the chemicals used in killing off brush. Mesquite was successfully controlled with light oils, kerosene, diesel fuel and similar oils. However, care should be taken to maintain a soil cover on sprayed areas to insure a minimum amount of damage by soil erosion.

Fisher, C. E. 1949. Is 2,4-D the answer to mesquite control? Farm and Ranch 68(5):29. (Asst. Soil Conserv., Texas Agr. Exp. Sta.; research conducted at Spur, Texas).

The answer is no, but experiments show that chemicals of this type will work under certain conditions. However, more research is needed before these hormone-type chemicals can be generally recommended.

Glendening, G. E. 1949. Some probable future developments in control of noxious range plants. J. Range Manage. 2:149-152. (Southwestern Forest and Range Exp. Sta., Tucson, Ariz.; research conducted in southern Arizona).

The rapid development and application to range lands of selective sprays has completely changed our attitude toward the control of noxious range plants, only a few years ago considered impractical. 2,4,5-T is suggested as more toxic than 2,4-D on most woody plants. Chemicals of the 2,4-D type have been produced so rapidly that over 1000 exist, most of which have not yet been tried out except in laboratory screening tests. Trends in methods of applying chemicals, and equipment for applying them, including airplanes, are discussed. Some types of heavy machinery in use on large expanses of relatively level rangelands are described. Biological control, though not regarded as the most effective means, deserves further investigation. While chemical substances herbicidal to perennial grasses are not of interest generally, use of such salts as ammonium trichloroacetate to suppress

Glendening 1949 (con't.)
emergence of annual grasses is of interest. Oils used alone and in combination with other toxic substances may be valuable.

Martin, S. C. 1949. Controlling mesquite with diesel oil. The Cattleman 36(5):56-57, 80. (Range Conser., Southwestern Forest and Range Exp. Sta., Tucson, Arizona; research conducted in southern Arizona).

Use of plenty of oil to control the mesquite, 1 gal is adequate for 5 to 7 trees. The stump should be soaked thoroughly to prevent underground growth. Cost is about 4.1 cents/tree.

Anon. 1950. New brush killer formulations. Down to Earth 5(4);20.

(Credentials unknown).

Two new brush killers, Esteron Brush Killer and Esteron 245, have been released by Dow Chemical Co. They have shown promise in preliminary field tests at the company research center.

Anon. 1950. Progress with dormant brush control. Down to Earth 5(4):8.

(Credentials unknown).

Chemical brush control must be year-around treatment in order to succeed. 2,4,5-T appears to be very promising for use in dormant applications. Spraying dormant brush is still in its infancy and much work needs to be done to prove or disprove its effectiveness.

Fisher, C. E. 1950. Mesquite control. Down to Earth 5(4):5-7.

(Credentials unknown).

Description of work at Spur, Texas on the problem of mesquite control. Control may be effected by oils, hand methods, mechanical means (cabling, bulldozing, etc.) and chemicals. 2,4-D and 2,4,5-T were used, and are proving effective in cleaning out the mesquite. However, more experimental and field work needs to be done.

Parker, K. W. and S. C. Martin. 1952. The mesquite problem on southern Arizona ranges. U.S. Dep. Agr. Circ. No. 908. 70p. (Range Cons. Southwestern Forest and Range Exp. Sta., Tucson, Ariz.; research conducted on the Santa Rita Exp. Range, Ariz.).

Southern Arizona rangelands constitute an important part of the State's grazing resource. These lands are grazed chiefly by cattle and when in good condition produce abundant nutritious native forage. The range forage produced normally supports upwards of a quarter million cattle valued at some 25 to 50 million dollars. Most of these animals are grazed in the eastern half of the area, including about 15 million acres; the western part being extremely arid. The climate is so mild as to encourage yearlong grazing use. Only a small amount of supplemental feeding is required. One of the major problems of animal production within this region arises from the reduction of the forage supply due to undesirable competing vegetation.

One of the most serious and perplexing problems in southeastern Arizona is mesquite invasion of grasslands. Mesquite occurs there in varying degrees of abundance on 9 million acres of rangeland. The problem is likewise serious elsewhere in the Southwest. Mesquite is now firmly established on considerably more than 70 million acres of range in Texas, New Mexico, and Arizona. An estimated half of the area now occupied by mesquite has been invaded since the advent of domestic livestock. The increase of mesquite is viewed with ever-increasing alarm by range operators.

Blair, B. O. and G. E. Glendening. 1953. Intake and movement of herbicides injected into mesquite. Bot. Gaz. 115:173-179. (Range Conserv. Southwestern Forest and Range Exp. Sta., USDA-FS, Tucson, Ariz.; research conducted on the Santa Rita Exp. Range, Ariz.).

1. Aqueous solutions of 2,4-dichlorophenoxyacetic acid (2,4-D), 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), eosin, sodium chlorate, ammonium sulfamate, and sodium arsenite were injected for 1 min in absence of air into mesquite stems. Injections were made in April, July, August, and December, during periods 5:00 am to 9:00 am and 1:00 pm to 3:00 pm, representing maximum and minimum diurnal relative humidity. Additional injections for periods varying from 10 sec to 48 hr were made in August.

2. On the basis of these findings, it appears that injection of herbicides into mesquite stems should be most effective if made while the trees are dormant, as in December, since maximum absorption and most extensive downward transport may be expected at that time.

Blair and Glendening 1953 (con't.)

Where an injection process is employed, application of systemic poisons should be most effective if made during the afternoon when minimum relative humidity and resultant maximum absorption occur. The nearly complete lack of lateral movement and the limited amount of downward movement of both organic and inorganic materials when introduced into mesquite stems suggest that herbicides, to be effective, should be applied so as to encircle the stems completely, and as close to the stem base as possible. The high degree of toxicity of sodium arsenite and the rapid and extensive movement of this material indicate why it is so effective when applied to freshly cut surfaces on the stems of velvet mesquite and other trees.

Roach, M. E. and G. E. Glendening. 1956. Response of velvet mesquite in southern Arizona to airplane spraying with 2,4,5-T. J. Range Manage. 9:70-73. (Range Conserv., USDA-ARS and USDA-FS, respectively; research was conducted on the Santa Rita Exp. Range, Arizona).

Tests were made of the effects of ester and amine forms of 2,4,5-T volume of spray application, ratio of oil-water in the carrier, diesel oil and nontoxic oil, and site on spraying of velvet mesquite by airplane at the Santa Rita Experimental Range and two cooperating ranches in southern Arizona in 1951.

The percentage plant kills ranged from 5 to 65 for different treatments at different sites, and averaged 23.6% for all tests. Percentage top kills ranged from 58 to 91 and averaged 75.8% for all treatment on all sites.

Site differences caused much variation in results. The ester of 2,4,5-T was much superior to the amine at one site and slightly superior at a second site, but the two forms were almost equally effective at a third site. The most effective volume varied with site and with formulation, but 10 gal/acre gave the best average results. At the Santa Rita Experimental Range comparisons of oil-water ratio (1:3 vs. 1:7) and oil (diesel oil vs. nontoxic oil) showed the 1:3 ratio was only slightly superior and diesel oil was as good or better than the nontoxic oil.

Fisher, C. E., C. H. Meadors, R. Behrens, E. D. Robison, P. T. Marion, and H. L. Morton. 1959. Control of mesquite on grazing lands. Texas Agr. Exp. Sta. Bull. No. 935. Texas A&M University. College Station. 24p. (Super. of Substation No. 7, Spur, Texas, Tech., Plant Physiologist USDA-ARS; Asst. Agron., Assoc. Animal Husbandman, Research Agron. USDA-ARS, respectively; research conducted at Spur, Texas.

Mesquite is an aggressive, deep-rooted, undesirable woody, sprouting shrub that occurs on approximately 55 million acres of grazing lands in Texas.

Economical control of mesquite on grazing lands depends largely on the selection of methods that will provide the greatest sustained benefits for the money expanded. Where mesquite thrives, no single method or practice will give effective and economical control under widely varying conditions. Good range and livestock management are essential to obtain maximum benefits from the control of mesquite. The chief value of controlling mesquite is to increase the density, vigor and production of palatable range forage species.

Some of the factors that influence the effectiveness and cost of controlling individual plants, in thin, open stands by hand or power grubbing, oiling with kerosene and diesel fuel and basal application of 2,4,5-T and soil application of monuron are discussed in this bulletin.

Factors that influence the effectiveness and cost of controlling moderate to dense stands by chaining and cabling, use of heavy-duty brush cutters, root plowing and aerial application of 2,4,5-T are enumerated.

The benefits of mesquite control include increased carrying capacity of the grazing lands, reduced cost of handling livestock and more efficient use of other range improvement practices.

Reinfestation of grazing lands by mesquite is aided by the dissemination of large numbers of viable seed by cattle, horses, sheep and rodents, the apparent lack of palatability of mesquite foliage to most grazing animals and the failure to maintain a heavy competitive cover of perennial grasses because of overgrazing, drouth and other factors.

The values of mesquite are limited largely to utilization of the beans by grazing animals. Some use also is made of the wood for fuel, fence posts and a source of roughage for feeding livestock. Additional uses include gum, preparation of charcoal and other special products.

Tschirley, F. H. and H. M. Hull. 1959. Susceptibility of velvet mesquite to an amine and an ester of 2,4,5-T as related to various biological and meteorological factors. Weeds 7:427-435. (Range Conserv. and Plan Physiologist USDA-ARS, Tucson, Ariz.; research conducted in southern Arizona).

An ester and an amine of 2,4,5-T were tested at frequent intervals from April 29 to July 1, 1955 on velvet mesquite. The ester of 2,4,5-T was consistently more effective than the amine under the conditions of this experiment, and its period of maximum effectiveness was longer. In addition, the difference in effectiveness between the ester and the amine salt increased as the season progressed. The optimum growth stage for application of the ester is defined as that time when leaves are full size but still succulent, flower development is complete, and the pods have started developing.

Air and soil temperature, relative humidity, stage of growth, leaf moisture, and the nature and content of carbohydrates in the root xylem at time of treatment were determined in an attempt to find some quantitative measure for evaluating mesquite susceptibility to 2,4,5-T. Of the factors measured, only stage of growth appears to be a moderately reliable criterion of susceptibility. The qualitative nature of determining stage of growth is not ideal, but quantitative measurements of the physical and physiological factors described were not correlated with susceptibility in this test.

Behrens, R. and H. L. Morton. 1960. Mesquite root inhibition tests to study inhibitory activity, absorption and translocation of 2,4-D and 2,4,5-T. Weeds 8:427-435. (Assoc. Prof., Dep. of Agron. and Plant Genetics, Univ. of Minn., St. Paul, Minn., and Research Agron. USDA-ARS College Station, Texas; research conducted in the laboratory).

The inhibition of mesquite root elongation was used to study the inhibitory activity, absorption and basipetal translocation of sub-lethal concentrations of 2,4-D and 2,4,5-T. The inhibitory activity of 2,4-D exceeded that of 2,4,5-T when these compounds were added to the cotyledons. Root inhibition was first apparent from 4 to 6 hr after cotyledonary applications. Ethanol, diesel fuel and acetone nontoxic oil carriers did not readily penetrate mesquite cotyledons unless the epidermis was ruptured. Absorption of 2,4,5-T by cotyledons was greatest when acetone-nontoxic oil was used as carrier. The effectiveness of the carriers correlated with the surface area wetted

Behrens and Morton 1960 (con't.)

by the drop applied. Repeated application of 2,4-D and 2,4,5-T to the cotyledons caused little or no impairment of basipetal translocation 48 to 72 hr after initial application.

Darrow, R. A. 1960. Aerial application of herbicides for brush and weed control. Texas Agr. Prog. 6(2):19-23. (Head, Dep. of Range and Forestry, Texas A&M Univ., College Station, Texas; summary of Brush Control Research).

Klingman, D. L. and W. C. Shaw. 1962. Using phenoxy herbicides effectively. U.S. Dep. Agr. Farm. Bull. No. 2183. 24p. Washington, D.C. (USDA-ARS; summary of application rates and methods).

Phenoxy herbicides--chiefly 2,4-D, 2,4,5-T, silvex, MCPA, and 4-(2,4-DB)--are used widely. They are used for controlling weeds in many crops, on grazing lands, and on lawns, and for killing unwanted brush and trees. These herbicides are especially useful because--

--They are selective; they kill most broadleaf plants but do not kill grasses or grain crops.
--They are potent; many species of weeds are controlled by less than 1 lb of active ingredient per acre.
--They are easy to use.
--They are not poisonous to man, domestic animals, fish, or game when applied at the recommended rates.
--They do not accumulate in the soil and they have no unfavorable effects on soil organisms.
--They are not corrosive to spraying equipment.

Tschirley, F. H. 1962. Controlling mesquite with 2,4,5-T. The Univ. of Arizona and U.S. Dep. Agr. Coop. Folder 98. 6p. (Range conserv. USDA-ARS; research conducted in southern Arizona).

The presence of mesquite on Arizona rangelands is a serious problem for ranchers who are interested in maximum beef production. Numerous studies have shown that mesquite competes severely with native perennial grasses for the available soil moisture. Controlling mesquite may more than double the production of perennial grasses in areas with a high potential for grass production.

Robison, E. E. 1963. Chemical brush control in West Texas. Texas Agr. Prog. 9(3):3-5. (Asst. Range Scientist, Texas Agr. Exp. Sta.; research conducted at Spur, Texas).

Wagle, R. F. and E. M. Schmutz. 1963. The effect of fenuron on four southwestern shrubs. Weeds 11:149-157. (Assoc. Watershed Special. and Research Asso., Univ. of Ariz.; research conducted in southern Ariz.).

The injurious effects of different rates of fenuron on four species of brush were recorded for 2 years in two different types of southwestern brushlands, the Oak-chaparral and the Chihuahuan Desert Shrub. Fenuron was more injurious to fire sprouts than to mature plants of turbinella oak in the Oak-chaparral type especially at 2 to 8 lb/acre a.i. The effects of fenuron on mature plants were reduced by burning, suggesting that much of the fenuron absorbed was residual in the stems, twigs, and leaves where it was destroyed by the fire. The effect of fenuron on the fire sprouts changed only slightly between 6 months and 2 years. Gibberellic acid was applied to sprouts and mature oak plants appeared to slightly reduce the injurious effects of some rates of fenuron during the first 6 months but no gibberellin induced differences were observed after 2 years. In the Chihuahuan Desert shrub type, tarbush was about equally susceptible to injury by fenuron with creosotebush slightly more resistant. Summer applications just before the rainy season were most effective and 4 lb/acre combined high shrub kill with greatest grass growth.

Although 8 and 15 lb/acre a.i. killed and injured both grasses and shrubs on the oak plots, grass naturally reseeded into these plots within 6 months after treatment, but on the Chihuahuan Desert area grass had not recovered on the plots treated at 8 lb/acre after 2 years. This difference in grass establishment was probably due to rainfall differences which would give differences in leaching of fenuron. Palatability of the grasses in the oak plots increased due to fenuron treatments, particularly on the heavily treated plots. These studies indicate that moderate rates of fenuron, applied just prior to favorable seasonal rains and repeated at several year intervals, may be used to control turbinella oak sprouts and mature Chihuahuan Desert shrubs. However, treatments would only economical where high forage and watershed values would result.

Davis, E. A. 1964. Picloram: a promising brush control chemical. U.S. Dep. Agr., Forest Service Research Note RM-35. 2p. (Plant Physiologist, USDA-ARS, Tempe, Arizona; greenhouse study conducted in Tempe, Ariz.).

Although the results of this study indicate that a single low-volume spray (such as an aerial application) probably would not be effective for eradicating shrub live oak, they suggest that high-volume sprays with ground equipment may be of value. Picloram was active through both the roots and shoots of shrub live oak. This plant was much more effectively controlled, however, when picloram was applied to the soil rather than to the foliage. Picloram can be applied conveniently to the soil as pellets.

On the basis of these preliminary studies, conducted in the greenhouse, picloram shows considerable promise as a brush control chemical in Arizona.

Rudd, R. L. 1966. Pesticides and the living landscape. University of Wisconsin Press. Madison. 320p. (Assoc. Prof. of Zoology, Univ. of Calif., Davis; location where research conducted unknown).

Greer, H. A. L. 1967. Mesquite control in Oklahoma. Oklahoma Ext. Facts 1-67/7M. Science Serving Agr. No. 2760. Oklahoma State Univ., Stillwater. 4p. (Ext. Weed Control Spec., Coop. Ext. Service, Okla. State Univ., Stillwater; research conducted in Oklahoma.

Schuster, J. L. 1969. Redberry juniper control with picloram, p. 53-54. In, Noxious Brush and Weed Control Research Rep. ICASALS Spec. Rep. No. 33. Texas Tech Univ., Lubbock. (Chairman, Dep. Range and Wildlife Manage., Texas Tech Univ., Lubbock; research conducted near Post, Texas).

Schuster 1969 (con't.)

Ground spray application of Tordon 212 and Tordon 225 resulted in 100% plant kills when applied in July at the 1.0 and 2.0 a.i./100 gal rates. The .5 lb a.i./100 gal rate of both formulations appears less than optimum since plant kills were significantly less than at the higher rates. Even at this rate, however, plant kill was 73.3% for Tordon 225 and 86.7% for Tordon 212 by the end of the second growing season when applications were made in July. Only the June application of .5 lb a.i./100 gal Tordon 212 gave plant kills of less than 71%.

Based on the data, it appears that Tordon 225 and 212 are effective in controlling redberry juniper when applied at the 1.0 lb a.i./100 gal rate at either date. Tordon 225 appears to be slightly more effective since the June application of 225 at .5 lb a.i./100 gal resulted in a higher plant kill than the June application at the same rate.

Dry form applications of picloram in the form of Tordon 10K pellets at 2, 4, and 8 lb a.e./acre resulted in 100% top kill of all plants in the season of application. All plants appeared dead by the end of the first growing season but will be observed for regrowth in 1970.

Picloram is apparently absorbed very rapidly through the roots of redberry juniper. The chemical was applied on 3 sites in April 1969. Moisture conditions were excellent due to good rains in February and March and a 12 inch snow in March. Precipitation in May and June was adequate to maintain excellent growth conditions. The herbicidal effects were apparent within a month and by July (3 months) all leaves were brown and shedding. By October 1, all plants were 100% top killed.

All associated woody species in the study area were treated at the same rate as applied to junipers. Mesquite was not affected detrimentally at any rate, but pricklypear, javalinabush and lotebush were effectively controlled (100%), defoliated by all rates of Tordon 10K application. Similar rates (2, 4, and 8 lbs a.e./acre) gave 100% top kills on lotebush during 1969 in Hardeman County.

Bovey, R. W., M. L. Ketcherside, and M. G. Merkle. 1970. Comparison of salt and ester formulations of picloram. Weed Sci. 18:447-451. (Research Assoc. and Assoc. Profs., Dep. Soil and Crop Sci., Texas A&M Univ., College Station, Texas; field research conducted at Tivoli and Carlos, Texas).

Bovey et al. 1970 (con't.)

Under Texas conditions, the potassium salt of 4-amino-3,5,6-trichloropicolinic (picloram) usually was more effective than the isooctyl ester formulation for control of live oak (*Quercus virginiana* Mill.), yaupon (*Ilex vomitoria* Ait.), winged elm (*Ulmus alata* Michx.), huisache (*Acacia farnesiana* (L.) Willd.), and honey mesquite (*Prosopis juliflora* (Swartz) DC. var. *glandulosa* (Torr.) Cockerell). Possible reasons for the difference in effectiveness of picloram formulations were studied in the laboratory. Extensive degradation of the ester of picloram (96%) occurred in open Petri dishes after 72 hr exposure to ultraviolet (uv) light, compared to a loss of 26% for the salt of picloram. Forty-five percent of the isooctyl ester of picloram was lost at high temperatures (60 C), whereas only 2% of the potassium salt of picloram was lost after 1 week at 60 C from open Petri dishes in a dark oven. Application of the ester to soils reduced thermal and ultraviolet degradation losses compared to losses from open Petri dishes. Loss of the ester was greater when applied in diesel oil to Petri dishes than in either water or paraffin oil. The salt of picloram leached most after 12.5 cm simulated rainfall in soil columns to the 17.5 to 30-cm level (907 μg), followed by the acid (360 μg), and last the isooctyl ester (0 μg). However, considerable acid (161 μg) was recovered at the 32.5 to 45-cm depth from the isooctyl ester treatment exposed to wet soils for 3 days, indicating hydrolysis of the ester to acid.

Hyzak, D. L., R. E. Meyer, and M. G. Merkle. 1970. Use of low volatile carriers to increase effectiveness of (2,4,5-Trichlorophenoxy)acetic acid. Texas Agr. Exp. Sta. Prog. Report PR-2813, p. 54-57. In, Brush Research in Texas. Consolidated Prog. Reports 2801-2828. Texas A&M University. College Station, Texas. (Former Grad. research Asst., Dep. of Soil and Crop Sci., Plant Physiologist, CRD, ARS, USDA, Dep. Range Science, Assoc. Prof. Dep. of Soil and Crop Sci., Texas A&M Univ., College Station, Texas; research conducted in the greenhouse).

Foliar absorption of a 2-ethylexyl ester formulation of 2,4,5-T applied in glycerol:water (1:1) or paraffin oil was compared to that absorbed when applied in water or diesel oil under greenhouse conditions. Honey mesquite was treated at rates of 1/16 and 1/4 lb/acre in 8 gal of carrier. The absorption of 2,4,5-T was highest with diesel oil, followed by paraffin oil, glycerol:water (1:1) and water. Dwarf yaupon was treated at rates of 0.5 and 2 lb/acre in 8 gal /acre of carrier. Again absorption was highest with diesel oil, followed by glycerol:water (1:1), paraffin oil and water.

Hyzak et al. 1970 (con't.)

Percent defoliation and leaf harvest data taken 4.5 months after treatment indicate that paraffin oil was more effective as a carrier than diesel oil, glycerol:water (1:1) or water.

Meyer, R. E. 1970. Influence of 2,4,5-T and picloram on the morphology and anatomy of honey mesquite. Texas Agr. Exp. Sta. Prog. Report PR-2819, p. 72-74. In, Brush Research in Texas. Consolidated Prog. Reports 2801-2828. Texas A&M University, College Station, Tex. (Plant physiologist, CRD, USDA-ARS, Dep. of Range Science, Texas A&M University, College Station; research conducted in the greenhouse).

Elongation of germinating honey mesquite seedling hypocotyls and roots are progressively inhibited by increasing concentrations of picloram and 2,4,5-T up to about 1 or 2 mg/liter the first 2 days. After 5 and 10 days, progressively more inhibition occurred at 5 to 10 mg/liter of 2,4,5-T and 1 to 2 mg/liter of picloram. The hypocotyl, collar and roots were larger in treated than in untreated 5-day-old seedlings largely from increased cortical thickness and proliferation of the endodermis and pericycle. The cells were multi-septate with enlarged nuclei.

Four-month-old honey mesquite seedlings were treated with 1/32, 1/8, and 1/2 lb/acre. Both herbicides caused curling of the stem tip and death of the growing point. Stems of treated plants frequently cracked immediately below the leaf. Treated plants produced numerous lateral roots. Picloram killed more plants than did 2,4,5-T.

Anatomically, the epidermal, outer cortical and pith cells remained normal. The phellem cells of the hypocotyl and main root enlarged radially, and many cells disintegrated. The inner cortex and phloem parenchyma, including the ray cells, proliferated. The cambium cells frequently differentiated into parenchyma when growth stopped leaving no definite teer of fusiform initials. The xylem vessels of the treated plants, under the influence of the herbicide, lignified but failed to enlarge normally. However, surviving plants produced new normal phloem and xylem cells within 53 days after treatment. Starch granules disappeared from xylem and pith parenchyma of treated plants within 8 days and recurred in treated plants 53 days after spraying.

Hoffman, G. O. 1971. Practical use of Tordon 225 Mixture herbicide on Texas rangelands. Down to Earth 27(2):no page numbers on reprint. (Ext. Range Brush and Weed Control Spec.; location where research conducted unknown).

Data for residue of picloram in soil, runoff water and grass were obtained from areas treated with 0.25 gal/acre TORDON 225 Mixture for honey mesquite control and up to 1.0 gal/acre for control of mixed brush species.

The amount of picloram residue remaining on grass 72 to 170 days following commercial application varied from none to 6.9 ppm. This does not present a hazard to animals grazing treated areas. Furthermore, data from Dow show no apparent ill effect in livestock from feeding levels as high as 1600 ppm picloram in the total daily diet continuously for 8 weeks. In Texas, the recommendation is that any brush controlled areas be deferred from grazing for 90 days following treatment to allow maximum forage growth.

Picloram did move from treated areas in surface runoff water when rainfall was received shortly after application, but residue could not be detected 120 days later.

Areas treated with TORDON 225 Mixture will remain in grasslands, since these acreages are not suitable for cultivation without irrigation. TORDON 225 Mixture herbicide can be used safely in Texas without causing lasting contamination of soil, water or forage on treated areas.

Meyer, R. E., R. W. Bovey, T. E. Riley, and W. T. McKelvy. 1972. Leaf removal interval effect after sprays to woody plants. Texas Agr. Exp. Sta. Bull. B-1127. 19p. (Plant physiologist, Research Agron., Biol. Research Tech., and Agr. Research Tech. USDA-ARS, Texas Agr. Exp. Sta.; research conducted near Bryan, Texas).

Greenhouse grown honey mesquite, huisache, whitebrush, field grown honey mesquite, huisache, whitebrush, live oak, Arizona ash, and winged elm were defoliated at several intervals following spray treatments with 4-amino-3,4,5-trichloropicolinic acid (picloram), 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), or (4-chloro-o-tolyl) oxy)acetic acid (MCPA). The time required by leaves to be retained on the plant after spraying to give maximum canopy reduction or death of plants varied among species. In most species, however, herbicide absorption and transport were complete within a 4-day period or less as compared to undefoliated treated plants.

Davis, F. S., R. E. Meyer, J. R. Baur, and R. W. Bovey. 1972. Herbicide concentrations in honey mesquite phloem. Weed Sci. 20:264-267. (Assoc. Prof., Texas Agr. Exp. Sta., and Plant Physiologist, Research Agron., USDA-ARS, College Station, Texas; research conducted near Bryan, Tex.).

Herbicide content in honey mesquite phloem 48 hr after treatment was higher in stems within 20 cm of the foliage than in those near the soil line. Similar levels of (2,4,5-trichlorophenoxyacetic) acid (2,4,5-T) occurred from applications of either 0.56 or 1.12 kg/ha, whereas three times as much 4-amino-3,5,6-trichloropicolinic acid (picloram) occurred in plants sprayed with the high rate than in those sprayed with the low rate. Herbicide concentrations were highest in June and lowest in August.

Sosebee, R. E. 1972. Enhanced effectiveness of 2,4,5-T with synergists. Southern Weed Sci. Sco., Proc. 25:430-435. (Asst. Prof., Dep. Range and Wildlife Manage., Texas Tech Univ.; research conducted near Post, Texas).

Elwell, H. M. and W. E. McMurphy. 1973. Weed control with phenoxy herbicides on native grasslands. Oklahoma Agr. Exp. Sta. Bull. No. 706. Oklahoma State Univ. 22p. (Research Agron., USDA-ARS, and Assoc. Prof., Oklahoma Agr. Exp. Sta., Stillwater, Oklahoma; location where research conducted unknown).

The herbicide 2,4-D was just as effective and more consistent in producing good weed control than 2,4,5-T, silvex and dichlorprop.

Hoffman, G. O. 1973. Putting research into action---guidelines for mesquite control, p. 71-74. In C. J. Scifres (chm.), Mesquite. Research Monogr. No. 1. Texas A&M University. College Station.

GUIDELINES FOR CHEMICAL CONTROL OF MESQUITE BY INDIVIDUAL-PLANT TREATMENTS

Kind and size of brush	Application: Method	Application: Season	Chemical mixture	Kind of equipment needed
Mesquite sprouts and seedlings only- sprouts at least 4 years old and 6 ft tall.	Foliage spray, complete and thorough wetting of foliage.	April, May, June, adequate soil moisture and good growth conditions.	2,4,5-T at 3 lb./100 gal water plus 16 oz surfactant.	Power sprayer or knapsack hand sprayer at pressure of 40 PSI or less at nozzle. Use orifice to produce large droplets.
Mesquite sprouts seedlings, granjeno, huisache, cactus, twisted acacia, skunkbush, catclaw acacia, whitebrush and other susceptible species.	Same as above.	Same as above.	Picloram + 2,4,5-T at 2 lb./100 gal water plus 16 oz. surfactant.	Same as above.
Mesquite, huisache, twisted acacia, cactus, granjeno, lotebush, algerita, catclaw acacia.	Trunk base, (trees less than 5 inches diam).	Anytime when soil is dry and not fused to tree trunk.	2,4,5-T at 8 lb./100 gal diesel oil or kerosene.	Knapsack hand sprayer or power sprayer, 40 PSI or can with pouring spout.
	Frill or stump, (trees over 5 inches diam).	Same as above.	Same as above.	Same as above.
Yucca—all sizes.	Crown bud spray.	Same as above.	Same as above.	Same as above.
Mesquite, all oaks, Texas persimmon, and other brush species not listed above. All sizes.	Trunk base, frill or stump.	Anytime when soil is dry and not fused to tree trunk.	2,4,5-T at 16 lb./100 gal diesel oil or kerosene.	Knapsack hand sprayer or power sprayer, 40 PSI at nozzle, or can with pouring spout.
Mesquite, huisache. All sizes.	Basal pour.	Same as above.	Diesel oil or kerosene.	Hand or power sprayers or can with pouring spout.
Mesquite and huisache sprouts.	Soil surface, individual plant treatment.	Spring, from bud growth to full leaf development.	Monuron pellets, 25% active ingredients, at 1 tbsp/inch of stem.	Hand application.
Mesquite, huisache, all oaks, all trees.	Same as above.	Same as above.	Monuron pellets, 25% active ingredients, at 1 tsp/4 inches of diameter stem.	Hand application.
Mesquite, algerita, lotebush, catclaw acacia, and other shrubby plants, all sizes.	Same as above.	Same as above.	Monuron 25% active ingredients at 1 tsp/ft of crown spread diameter. Second application may be needed.	Hand application.

GUIDELINES FOR CONTROL OF MESQUITE WITH BROADCAST APPLICATIONS OF HERBICIDES

Kind and size of mesquite	Application: Method	Application: Season	Herbicide or mixture[1]
Tree-type. All trees or sprouts at least 4 ft tall and 4-6 years old with dense foliage.	Foliage, air broadcast, spray-swath widths adequate to insure complete foliar coverage.	Spring, under good growth conditions, 40 to 90 days after first green growth appears at the bud with dark green foliage and soil temperatures of over 70°F.	2,4,5-T at 0.5 lb./acre in West Texas and 1 lb./acre in South Texas. 1 gal diesel oil and water to make 4 to 5 gal/acre solution. Picloram + 2,4,5-T at 0.5 lb./acre in West Texas and 1 lb./acre in South Texas in 1 gal diesel oil + special emulsifier and water to make 4 to 5 gal/acre solution. Dicamba + 2,4,5-T at same rates as for 2,4,5-T or for picloram + 2,4,5-T
Creeping-type. All growth forms—original and sprouts with dense foliage.	Foliage, spray-swath widths to insure complete coverage, two to three applications as necessary in successive years, limited to South Texas Plains.	Spring, under good growth conditions, 40 to 90 days after first green growth appears at the bud.	2,4,5-T at 0.67 lb./acre in 1 gal diesel oil and water to make 5 gal/acre solution. Use picloram + 2,4,5-T for second and third sprayings if site contains cactus, huisache, granjeno, twisted acacia, or other susceptible mixed-brush species.
Mesquite of all sizes with understory of perennial weeds.	Foliage spray, air or ground broadcast.	Spring or fall, after fall moisture. No effect on mesquite in fall.	Picloram + 2,4,5-T or dicamba + 2,4,5-T at 1 lb./acre. Use water or oil:water emulsion at 4 gal/acre.

[1]Where rates of mixtures are given, herbicides in combination should be used in equal ratios.

Meyer, R. E. and R. W. Bovey. 1973. Control of woody plants with herbicide mixtures. Weed Sci. 21:423-426. (Plant Physiologist and Agronomist, USDA-ARS College Station, Tex.; field research conducted near Bryan and Marble Falls, Texas).

Honey mesquite (*Prosopis juliflora* (Swartz) D.C. var. *glandulosa* (Torr.) Cockerell), huisache (*Acacia farnesiana* (L.) Willd.), Macartney rose (*Rosa bracteata* Wendl.), and whitebrush (*Aloysia lycioides* Cham.) were sprayed with herbicides alone and in mixtures. Mixtures of picloram (4-amino-3,4,6-trichloropicolinic acid) + dicamba (3,6-dichloro-o-anisic acid) at 0.56 + 0.56 and 1.12 + 1.12 kg/ha were most effective for killing honey mesquite in July. Picloram or picloram + dicamba were more effective for defoliating huisache than 2,4,5-T (2,4,5-trichlorophenoxy)acetic acid), dicamba or other mixtures of herbicides. On Macartney rose, picloram as the salt or ester was most effective, but some mixtures of picloram plus either 2,4-D (2,4-dichlorophenoxy)acetic acid) or 2,4,5-T were as effective as picloram alone. On live oak, the most effective treatments generally contained at least 1.12 kg/ha of picloram either alone or in mixtures with dicamba or 2,4,5-T. Picloram alone killed as many or more whitebrush plants than MCPA, dicamba, 2,4,5-T, 2,4-D, or mixtures.

Scifres, C. S., J. R. Baur, and R. W. Bovey. 1973. Adsorption of 2,4,5-T applied in various carriers to honey mesquite. Weed Sci. 21:94-96. (Assoc. Prof., Dep. Range Science and Research Plant Physiologist and Research Agron., USDA-ARS, College Station, Texas; greenhouse study conducted at Texas A&M University).

Absorption of the butyl ether ester of 2,4,5-T by honey mesquite foliage was more rapid when 0.56 kg/ha was applied in 15 liter/ha paraffin oil than when diesel oil, water, or emulsions of the oils in water were used as carriers. However, carrier had little effect on 2,4,5-T translocation to stems or roots. The percentage of greenhouse-grown honey mesquite plants killed was reduced when 2,4,5-T was applied in diesel oil as compared to other carriers studied.

Scifres, C. J., R. W. Bovey, C. E. Fisher and J. R. Baur. 1973. Chemical control of mesquite, p. 24-32. In, C. J. Scifres (Chm.), Mesquite. Research Monogr. No. 1. Texas A&M University. College Station. (Assoc. Prof., Tex. Agr. Exp. Sta., Agron., USDA-ARS, Prof., Texas Agr. Exp. Sta., Lubbock, Plant Physiologist USDA-ARS; research conducted throughout Texas).

The advent of the highly selective phenoxyacetic acid herbicides, especially 2,4,5-T, revolutionized the approach to mesquite control. Since its introduction, intensified research has been directed toward developing safer and more effective herbicides and application techniques.

Regardless of the herbicide, additive, carrier or application technique, foliar applications are presently more feasible for control of dense infestations of mesquite. Aerial-application of 2,4,5-T at about 0.5 lb/acre is the most widely used method. Soil-applied, substituted urea herbicides such as monuron and fenuron are effective, but dicamba granules and picloram pellets have proved ineffective.

Mesquite is most susceptible to foliar sprays at 40 to 90 days after first leaves emerge in the spring. Any environmental factor which limits growth and development limits effectiveness of the sprays. The leaves must be fully developed and turning dark green but not too heavily cutinized to allow entry of the herbicides from the leaves through the stems to the crown and roots. These conditions generally occur from mid-May to July 1. The time of movement of greatest amounts of food materials from leaves coincides closely with maximum movement of herbicides in mesquite. Maximum canopy development and area are undoubtedly prime requisites for optimum activity of foliar applied herbicides.

Although the addition of picloram to 2,4,5-T usually increases the number of mesquite plants killed, effectiveness of the combination is probably regulated by the same factors that influence the activity of 2,4,5-T alone. The addition of picloram to 2,4,5-T also has usually increased the range of associated undesirable species controlled. Although the combination of dicamba with 2,4,5-T has not proved synergistic, indications are that several associated weed species are more susceptible to the mixture than to 2,4,5-T alone.

Many carriers and additives have been tested for the application of herbicides to mesquite. None have proved consistently superior to a 1:3 or 1:4 diesel oil:water emulsion. However, some recent experiments indicate improved drift control with certain oil carriers over that of the standard emulsion.

Fisher, C. E., C. H. Meadors, J. P. Walters, J. H. Brock, and T. H. Wiedemann. 1974. Influence of volume of herbicide carriers on control of honey mesquite. Texas Agr. Exp. Sta. Prog. Rep. PR-3282. Texas A&M University, College Station, Texas. 4;. (Prof., Research Assoc., Asst. Prof., Research Assoc., and Asst. Prof., Texas Agr. Exp. Sta., Vernon, Texas; research conducted throughout Texas).

Herbicides aerially applied in volumes of 0.5, 1 and 4 gal/acre of a 1:3 diesel oil-water emulsion carrier for control of mesquite were studied from 1969 to 1973.

Compared with the conventional 4-gal volume/acre, application of 1 gal/acre of the carrier reduced the amount of diesel oil by 86%, water by 78%, aviation fuel required by 31%, and time required to spray a given acreage by 40%.

Variation in carrier volumes from 0.5 to 4.0 gal/acre containing 0.25 to 0.5 lb of 2,4,5-T/acre of 0.5 lb/acre of 1:1 combination of 2,4,5-T and picloram did not significantly affect the plant kill of honey mesquite.

Different carrier volumes did not appreciably affect the deposition of 2,4,5-T in the target area applied at low pressure with a minimum number of nozzles.

Fisher, C. E., C. H. Meadors, J. H. Brock, and B. T. Cross. 1975. Influence of volume of herbicide carriers on control of honey mesquite, p. 29. In, Rangeland Resources Research, 1971-1974. Texas Agr. Exp. Sta. Cons. PR-3341. Texas A&M University. College Station. (Prof. Tex. Agr. Exp. Sta., Lubbock, Research Assoc., Research Assoc., and Research Tech., Texas Agr. Exp. Sta., Chillicothe-Vernon; research conducted in Texas).

Research was undertaken in 1969 to develop safer, more effective and economical methods of aerial application of herbicides for the control of honey mesquite. Initial objectives of this study were to determine the influence of volume of herbicide carriers on (1) plant kills of honey mesquite, (2) deposition of the herbicide in the target area and (3) efficiency of application with aerial spraying equipment. Herbicides

Fisher et al. 1975 (con't.)

used were 2,4,5-T low volatile esters (propylene glycolbutyl ether or butoxyethanol) and a 1:1 combination of 2,4,5-T and picloram as trimethylamine salts.

Variation in volumes of diesel oil:water emulsion from 0.5 to 4 gal/acre containing 0.5 lb/acre of 2,4,5-T or a 1:1 combination of 2,4,5-T and picloram did not significantly affect kill of honey mesquite. However, the combination of 2,4,5-T and picloram killed more plants than equivalent amounts of 2,4,5-T.

Hoffman, G. O. 1975. Control and management of mesquite on rangeland. Texas Agr. Ext. Ser. Misc. Publ. MP-386. Texas A&M University. College Station. 15p. (Ext. Range Brush and Weed Control Spec.; research conducted in Texas).

Mesquite is a natural component of most rangeland vegetation in Texas. Mesquite, honey, western honey, velvet and creeping all grow in Texas. Honey mesquite is the most widespread, with creeping growing in the Frio-Nueces river watersheds and with velvet and western honey occurring west of the Pecos River. In this publication, honey, western honey and velvet mesquite will all be referred to as mesquite.

Mismanagement of grazing lands, protection from fire, drouth, heavy concentration of livestock, fencing, and a combination of these factors have favored encroachment of mesquite. It is a problem on some 56 million acres of Texas rangelands. Grasslands that are heavily infested with mesquite often produce inadequate amounts of desirable forage for economic livestock production and provide poor habitat for wildlife.

Ecologically, mesquite is a strong competitor for water and plant nutrients; it is a profuse seed producer; it is a prolific sprouter; and it is not a preferred food item in the diet of any animal except at specific times during the year. At times, mesquite beans can even become toxic to grazing animals. However, mesquite has been utilized as a source of food for humans, animals, and birds. It also has been used for fuel, medicine, bleaching agent, charcoal, bowling pins, spurs, building material, fence posts, gun stocks and golf clubs.

Mesquite is an aggressive, deeply tap-rooted plant with many lateral roots. Since the seeds do not germinate readily unless scarified, they may lie dormant in the soil for periods of from 10 to 40 years. Established mesquite plants sprout profusely following damage of top growth. Although mesquite will sprout along the stem the main bud zone which is from 2 to 12 inches beneath the soil surface, is the main sprouting part. To be successful, then any control method must

Hoffman 1975 (con't.)

kill or destroy the top as well as the sprouting root-collar bud zone. Growth and reproduction characteristics of mesquite make it impossible to eradicate. However, control programs that reduce mesquite density also enhance the productivity of grassland ecosystems and are economically desirable for ranchmen to operate at a profitable level. To produce a pound of mesquite foliage requires 2 to 4 times more water than the production of a pound of desirable native forage, and the foliage of mesquite is low in palatability and of little value to livestock or wildlife except for shade.

Attempts at controlling mesquite with fire, mechanical, chemical and biological methods date back at least 40 years and probably earlier. Because of the sprouting regrowth characteristics of mesquite plant, fire as a control method is less effective than mechanical methods, such as grubbing, root plowing, stacking, chaining, etc., which remove the bud zone from the soil. Chemicals, both contact and growth regulator types, have been used widely since 1947. Contact-type herbicides, such as kerosene and diesel fuel oil, give excellent control but require considerable labor for application. Growth-regulating chemicals give only moderate control but can be applied by aircraft so that such herbicides can be used to treat large acreages with low labor expenditures. The search for a biological means of control is continuing.

It is likely that every owner or manager of rangelands would like to eradicate or selectively control mesquite with a single treatment and forget the problem. However, mesquite control is a complex problem. In northern areas of Texas, mesquite may be the only problem species while in the southern part of the state, mesquite may be only one of many species to be treated. In mixed stands of woody plants where mesquite is controlled the development of resistant species may rapidly become the major brush problem.

While mesquite cannot be eradicated, it can be controlled and managed. The control of weeds and other competing vegetation in agronomic crops is considered a production expense, and the same is true in the control of mesquite. While good range management is essential, management alone is not sufficient to overcome the mesquite problem. Once mesquite is established, no amount of management will thin it out or remove it. Control programs must be adapted to an area coupled with good range management. Such a program, considering cost-production-return, should extend over at least 20 years. Mesquite is capable of reestablishing itself from seed for at least 10 to 40 years even if no new seed is produced on the area. An example is following research conducted by the Texas Agricultural Experiment Station at Spur:

1940-218 trees removed
1945-109 seedlings removed
1952-185 additional seedlings removed
1964-107 additional seedlings removed
1972-107 additional seedlings needed to be removed

Hoffman 1975 (con't.)

Mesquite beans possibly could have been introduced into the area by rodents, birds and other wildlife animals over the 32 year period.

A program of mesquite control, coupled with good range management, provides the following advantages:

- Increases offspring weaning weights
- Permits an increase in stocking rates
- Increases desirable forage plants
- Reduces labor costs for handling of livestock
- Allows better distribution of livestock and utilization of forage
- Improves wildlife habitat
- Allows more efficient use of breeding males
- Reduces cover for predators and rustlers
- Improves water utilization with increased ground water yields
- Improves and enhances the total rangeland environment

Richardson, R. G. and R. L. Amor. 1975. Effect of 2,4,5-T and picloram on the regeneration of blackberry (*Rubus procerus* P.J. Muell) from root segments. Weed Res. 15:227-231. (Keith Turnbull Research Sta., Victoria, Australia; research was conducted at Keith Turnbull Research Station, Australia).

The formation of roots and shoots on root segments of blackberry was prevented by soaking the segments for 24 h in a 10^{-4}M solution of 2,4,5-T or a 10^{-5}M solution of picloram. Shoot numbers were significantly increased after treatment with 10^{-9}M and 10^{-10}M 2,4,5-T but picloram did not cause a significant increase in shoot numbers. Measurement of the concentration of 2,4,5-T in the extracambial tissue showed that roots treated with 10^{-4}M 2,4,5-T contained $5X10^{-8}$ mmole 2,4,5-T /mg dry weight, and by extrapolation, roots treated with 10^{-9}M 2,4,5-T contained $2X10^{-12}$ mmole/mg dry weight.

Scifres, C. J. and H. G. McCall. 1975. Comparative response of woody plants to esters and salts of 2,4,5-T and picloram, p. 23. In, Rangeland Resources Research, 1971-1974. Texas Agr. Exp. Sta. Cons. Prog. Rep. PR 3341. (Assoc. Prof. and Research Assoc. Texas Agr. Exp. Sta.; research conducted near Campbellton and Refugio, Texas).

Scifres and McCall 1975 (con't.)

The commercial combination of 2,4,5-T + picloram is formulated as triethylamine salts. Salt formulations are highly water soluble and are not highly prone to volatilization but are usually less compatible with waxy leaf surfaces than are esters. The isooctyl esters of 2,4,5-T + picloram were compared with the salt formulations near Campbellton and Refugio, Texas, relative to brush control and herbicide residue levels resulting in range forage. The 2,4,5-T + picloram (1:1) formulations were aerially applied at 1 lb/acre in a diesel oil:water emulation at 5 gal/acre.

In September 1974, 14 months after application, about 70% of the honey mesquite plants were completely defoliated and not resprouting regardless of 2,4,5-T + picloram formulation. There were no significant differences between the two formulations in the degree of control of whitebrush, Texas persimmon, agarito or spiny hackberry. Whitebrush control was erratic in all treatments with 40 to 45% of the population showing no effect of the herbicide. There was no control of Texas persimmon and agarito by either formulation, while approximately 90% of the spiny hackberry were completely defoliated, of which about 45% had not developed sprouts.

Immediately after spraying, picloram concentrations detected in native grasses from the salt and ester treatments were 225 and 175 ppm, respectively. At 2 weeks after treatment, picloram concentration had declined to around 35 ppm regardless of formulation. At 4 weeks after treatment, detectable picloram in forages was 6 to 7.5 ppm. The concentration of picloram continued to decline in range forage with time as shown by other research, and no difference due to formulation was detected. After 8 weeks, the forages contained about 0.25 ppm detectable residue.

Scifres, C. J., G. O. Hoffman, and H. C. McCall. 1975. Influence of spray volume on efficiency of aerial herbicide application for running mesquite control, p. 20. In, Rangeland Resource Research, 1971-1974. Texas Agr. Exp. Sta. Cons. Rep. PR 3341. Texas A&M University. College Station. (Assoc. Prof., Extension Range Brush and Weed Control Spec. and Research Assoc., Texas Agr. Exp. Sta.; research conducted near Tilden, Texas).

Scifres et al. 1975 (con't.)

Research has been conducted in the past 5 years to evaluate the possibilities of reducing the amount of aerial spray volume required to control woody plants with herbicides. However, the influence of spray volume on the reaction of running mesquite to 2,4,5-T, especially using large mono-wing aircraft, has not been evaluated.

Research was initiated in 1972 near Tilden, Texas, to compare 0.67 lb/acre of 2,4,5-T applied in 5 gal/acre of diesel oil:water emulsion (1:4) with 1 gal/acre of diesel oil for control of running mesquite. Blackbrush acacia, guayacan, pricklypear and whitebrush were also major components of the brush community. Running mesquite normally requires three consecutive annual applications of 2,4,5-T at 0.67 lb/acre for effective control. Using a swath 42 ft wide and a short ferry distance (less than 1 mile), the time for aerial application was 231 acres/hr at the standard application volume and 310 acres/hr using only 1 gal/acre. Fuel requirements to spray the areas were reduced by about 15 to 20% by using the lower application volume. Associated labor costs such as for flagmen, hauling, and mixing and loading were also substantially reduced with the reduction in spray time.

As in studies with other brush species, low volume application of herbicides reduced spraying time and amount of carrier solution required to complete treatment of running mesquite. However, special spraying equipment was necessary for application of proper spray droplet size with low volume application. Spray droplet size is directly influenced by spraying pressure and nozzle size. For instance, the use of standard nozzle systems, particularly the diaphragm system, generated a higher proportion of fine droplets in the sprays with 1 gal/acre than with 5 gal/acre. From 12 to 15 lb pressure/in^2 are required to open the diaphragms so that lower pressures could not be used. At 12 lb the average droplet diameter was seven times greater than when 5 gal/acre were utilized. However, continued refinements with the application system, such as with the Zeigler Spraying System which allows reduced spraying pressure, improved spray droplet size resulting from low volume application. After three consecutive annual applications, there was no difference between the spray volumes in control of running mesquite.

SUMMARY AND CONCLUSIONS

Herbicides are a class of pesticides that result in toxic effects on plants (Rudd, 1966). Therefore, any chemical compound that has been used to control mesquite (*Prosopis* sp.) is technically classed as a herbicide. Chemical control of mesquite has been attempted since the 1930's (Fisher 1942; Streets and Stanley 1938). Since that time to the present, numerous chemical compounds have been tested, but only a few have been used successfully. Some of the chemicals used in the earlier years of mesquite control included kerosene, diesel fuel, sodium arsenite, sodium chlorate, ammonium thiosyanate and ammonium sulfamate (AMS) (Scifres et al. 1973). Fuel oils plus cacodylic acid continue to be used to a limited extent, primarily as additives to herbicide solutions or as basal applications to individual plants.

Registered herbicides that are used to control mesquite almost to the exclusion of other herbicides include 2,4,5-Trichlorophenoxy acetic acid (2,4,5-T), 4-amino-3,5,6-trichloropicolinic acid (picloram) + 2,4,5-T (Tordon 225 Mixture®), 3,6-dichloro-o-anisic acid (dicamba), and dicamba + 2,4,5-T (Banvel 2+2®). Low volatile ester formulations, e.g. propylene glycol butyl ether ester, of 2,4,5-T (packaged at 4 lb a.e./gal) are applied alone or in mixtures with either picloram and dicamba. Effectiveness of either picloram or dicamba alone is dependent upon geographical location. Generally, dicamba is more effective in areas characterized by drier climates, e.g. far west Texas and New Mexico, whereas picloram is more effective in mesic climates.

Early research indicated that picloram was not effective when applied alone (Schuster 1969). Usually application of dicamba alone has not been recommended (Hoffman 1975). However, recent research by Texas Tech University, Texas A&M University, Texas Agricultural Experiment Station and New Mexico State University (all unpublished data) has indicated that either picloram or dicamba applied alone can sometimes control mesquite. Occasionally, 2-(2,4,5-trichlorophenoxy)-propionic acid (Silvex®) has been used to control mesquite (Meister 1978), however, it is not as effective as other herbicides.

Numerous herbicides have been studied during the past three decades in search of those with potential for mesquite control (Fisher 1959; Tschirley and Hull 1959; Behrens and Morton 1960; Darrow 1960; Robison 1963; Greer 1967; Hoffman 1971; Meyer et al. 1972; Meyer and Bovey 1973). Most of the herbicides tested over the years never succeed, therefore, they are not registered. Others are successful in controlling mesquite, but registration is difficult to obtain with present-day regulations. Although picloram has demonstrated effective control of mesquite, it is registered for use only in certain states. One liquid herbicide currently being studied that appears to be particularly promising is 3,6-dichloropicolinic acid (DOWCO 290). Others that have been studied to a limited extent and may have promise include the trichlopyr herbicides, one of which is [(3,5,6-trichloro-2-pyridinyl)-oxy] acetic acid, (Garlon®), formerly known as DOWCO 233 (Byrd et al. 1975; and Haagsma, 1975).

"Dry" herbicides (either pellets, granules, or wettable powder) have demonstrated some success in certain regions, although they have not been widely accepted. Substituted ureas such as 1,1-dimethyl-3-

phenylurea (fenuron, Dybar®) and 3-(p-chlorophenyl)-1,1-dimethylurea (monuron, Karmex®) have been used to effectively control mesquite in the more arid regions of the southwestern U.S. Dry herbicides that have demonstrated ability to effectively control mesquite in the Southwest, but not presently used extensively, are 2-methoxy-4,6-bis (isopropyl-amino)-1,3,5-triazine (Pramitol®), Banvel® 5G granules (dicamba), and 5-bromo-3-sec-butyl-6-methyluracil (bromocil, Hyvar X®). Tebuthiuron (N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2yl]-N,N'-dimethylurea) or GRASLAN®, still in the experimental phases, has effectively controlled mesquite on sandy soils (Sosebee 1978), but it is ineffective except at very high rates on heavy textured soils (R. Bjerregard, Plant Science Representative, Elanco Products Div., Lilly Research Laboratories, personal communication). Another substituted urea that has shown much promise is m-(3,3-dimethylureido) phenyl tert-butylcarbamate (Karbutilate, Tandex®).

Application rates vary with herbicide and geographic region where it is to be applied. Some of the earliest research on application rates of 2,4,5-T was conducted by Fisher (1959). Fisher (1959) concluded that 0.5 lb a.e./acre 2,4,5-T applied in a 1:3 mixture of diesel oil:water produced the highest root-kill in mesquite. However, the data of his study indicates there are no differences in root-kill from rates ranging from 0.25 to 1.0 lb a.e./acre (Table 1). Average root-kill of mesquite from 2,4,5-T applied in 1:3 diesel oil:water emulsion at six locations over a 4 year period ranged from 29 to 40%. Swath width and total volume also influenced amount of root-kill. Present recommendations for using 2,4,5-T to control mesquite are 0.5 lb a.e./acre in west Texas (Hoffman 1973) and southern New Mexico (Herbel 1970), 1.0 lb a.e./acre

Table 1. Effect of aerial swath width and various rates of 2,4,5-T on percentage kill of mesquite at six locations, 1954-57. (Fisher et al., 1959).

Swath width, (ft)	Pounds of 2,4,5-T (a.e./acre)	Volume gal 1:3 emulsion/acre	Root kill (%) [1/]
30	1/4	5.59	31
30	1/2	5.59	34
30	3/4	5.59	30
30	1	5.59	34
42	1/4	4.00	33
42	1/2	4.00	31
42	3/4	4.00	34
42	1	4.00	32
54	1/4	3.10	31
54	1/2	3.10	35
54	3/4	3.10	33
54	1	3.10	29
67	1/4	2.54	31
67	1/2	2.54	31
67	3/4	2.54	31
67	1	2.54	33
84	1/4	2.00	33
84	1/2	2.00	40
84	3/4	2.00	31
84	1	2.00	33

1/ Percentage root kill 15 months or longer after treatment.

in south Texas (Hoffman, 1973) and 0.33 lb a.e./acre in Arizona (Tschirley, 1962). Recommended rates of picloram plus 2,4,5-T are 0.5 lb a.e./acre (0.25 lb a.e./acre picloram plus 0.25 lb a.e./acre 2,4,5-T) in west Texas and 1.0 lb a.e./acre (0.5 lb a.e./acre picloram plus 0.5 a.e./acre 2,4,5-T) in south Texas. Recommendations are to apply dicamba + 2,4,5-T at the same rates as picloram plus 2,4,5-T (Hoffman, 1973).

Low volatile ester formulations of 2,4,5-T have been used almost to the exclusion of other formulations of 2,4,5-T to control mesquite (Tschirley and Hull, 1959; and Fisher et al., 1946). However, the amine salt formulations of 2,4,5-T are just as effective as ester formulations used to control several woody species (Scifres and McCall, 1975). Personal communications with H. M. Hull (Plant Physiologist, USDA-ARS, retired) indicated that examination of results of the ester and amine salt formulation of 2,4,5-T revealed essentially no differences 5 to 7 years after application. Our research (R. E. Sosebee and B. E. Dahl, unpublished data) from commercial applications of 2,4,5-T for several years (1970-1976) indicates there are no significant differences in root mortalities obtained from using either the amine (average root mortalities for all dates, 18.7%) or ester (average for all dates, 14.3%) formulation of 2,4,5-T.

Bovey et al. (1970) and Scifres and McCall (1975) showed that the potassium salt formulation of picloram more effectively controlled nursery plantings of mesquite than the isooctyl ester formulations possibly because salt formulation is not degraded as rapidly, as the isooctyl ester formulation. Tordon 225 Mixture originally contained the triethylamine salt formulation of picloram and 2,4,5-T (both of which are water soluble), yet diesel was recommended as an additive to the herbicide solution. Since neither herbicide formulation was soluble in oil, the question was raised relative to the addition of diesel. We (R. E. Sosebee and B. E. Dahl, unpublished data) initiated (1972-1974) of Tordon 225 sprayed with and without diesel added to the herbicide solution. Our results indicated there were no significant differences as a result of the addition of diesel. However, root mortalities of trees sprayed with Tordon 225 without diesel were higher (36.2%) than those sprayed with Tordon 225 to which diesel was added (30.9%). In the event of an energy crisis, or with the increased cost of petroleum products, elimination of diesel could represent a considerable reduction in herbicide application cost. Tordon 225E (the more recent formulation) contains the triisopropanolamine salt of picloram + the propylene glycol butyl ether ester of 2,4,5-T. Tordon 225E can be applied in water only, but for most applications, addition of diesel is recommended (oil:water ratio, 1:5).

Perhaps one of the most revolutionary discoveries in mesquite control by aerial application was reduction of the standard volume of 4 gal/acre herbicide solution to 1 gal/acre. When low volumes are used, low pressures (12 psi) must also be used to avoid drift problems (Fisher et al. 1975; and Scifres et al. 1975). Standard "low-volume" herbicide solutions (0.5 lb a.e. herbicide/acre) include 1 pint of herbicide, 1 pint of diesel and 3 quarts of water.

Effectiveness of herbicides is also dependent upon time of application relative to the physiological condition of the trees and the environmental conditions at the time of application. Rates less than 0.25 lb a.e./acre usually are not as effective as those higher, but 0.25 lb a.e./acre is often as effective as 0.5 lb a.e./acre in west Texas and eastern New Mexico (Table 2). Amount of carrier may also influence the effectiveness of an herbicide.

Table 2. Results of selected herbicides applied in various combinations and at various rates to mesquite in eastern New Mexico. Data extracted from 1967-1976 Brush and Weed Control Summary, Lea County, New Mexico.

Herbicide	Application Date	Rate (lb a.e./ac)	Volume (gal/ac)	Root Mortality (%) 1973	1974	1975
2,4,5-T	6/20/70	1/4	1	97		
2,4,5-T	6/20/70	1/2 (1:3 oil:water emulsion)	4	93		
2,4,5-T	6/15/71	1/2 (1:3 oil:water emulsion)	4	54		
2,4,5-T	6/15/71	1/2	1	37		
2,4,5-T	6/15/71	1/2 (1:1 oil:water emulsion)	2	59		
2,4,5-T	6/22/71	1/2 (1:3 oil:water emulsion)	4	22		
2,4,5-T	6/22/71	1/2	1	42		
2,4,5-T	7/03/72	1/4	1	45	88	
2,4,5-T	7/03/72	1/2	1	38	61	
Picloram	6/22/71	1/2 (1:3 oil:water emulsion)	4	47		
Dicamba	6/15/71	1/2	1	58		
Dicamba	6/15/71	1/4	1	57		
Dicamba	6/22/71	1/2	1	30		
Dicamba	6/22/71	1/2	1	28		
Picloram + 2,4,5-T	6/15/71	1/4 + 1/4 (1:3 oil: water emulsion)	4	53		
Picloram + 2,4,5-T	6/22/71	1/4 + 1/4	1	27		
Picloram + 2,4,5-T	6/22/71	1/2	1	34		
Picloram + 2,4,5-T	7/03/72	1/8 + 1/8	1	28	60	
Picloram + 2,4,5-T	7/03/72	1/4 + 1/4	1	44	62	
Dicamba + 2,4,5-T	6/18/70	1/8 + 1/8	1	28		
Dicamba + 2,4,5-T	6/20/70	1/4 + 1/4 (1:3 oil: water emulsion)	4	93		
Dicamba + 2,4,5-T	6/15/71	1/4 + 1/4	1	62		
Dicamba + 2,4,5-T	6/15/71	1/8 + 1/8	1	59		
Dicamba + 2,4,5-T	6/22/71	1/4 + 1/4	1	20		
Dicamba + 2,4,5-T	7/03/72	1/8 + 1/8	1	68	74	
Dicamba + 2,4,5-T	7/03/72	1/4 + 1/4	1	66	41	
Dicamba + 2,4,5-T	7/16/73	1/6 + 1/6	1		24	23

Research in eastern New Mexico indicates that there are several dry herbicides that are capable of controlling mesquite. Effectiveness is generally higher at lower rates on sandy soils than it is on heavier textured soils (Table 3).

Although "dry" herbicides have been available for research for several years, they have not received the same amount of attention as liquid herbicides. One reason for their lack of acceptance is related to the mode of application. Wettable powder formulations applied as a spray have not been effective in controlling mesquite. Therefore, application has been relegated to aerial broadcast of pellets and granules or ground application of wettable powder, pellets, or granules to individual plants. Fenuron and monuron have both been used successfully to control mesquite in southern New Mexico. Fenuron pellets (10% a.i.) should be scattered uniformily within the canopy area of mesquite at a rate of 1 g/ft of canopy on sandy soils (Herbel 1970). Rates should be increased for mesquite growing in heavier soils. Monuron (80% a.i. wettable powder) should be applied at the same rates as fenuron but it must be covered by the soil. Karbutilate demonstrated excellent promise for controlling mesquite in west Texas (G. O. Hoffman, Extension Range Brush and Weed Control Specialist, Texas A&M University, personal communication). Rates from 1 to 5 g a.i./tree (4 to 6 inch basal diameter, 6 to 8 ft tall) effectively controlled mesquite in the Rolling Plains of Texas (R. Sosebee, unpublished data). In 1974, research was initiated at Texas Tech on the effect of tebuthiuron on mesquite growing in sandy soil. Control was effected at rates ranging from 2 to 8 lb a.i./acre (R. Sosebee, unpublished data).

Table 3. Results of selected dry herbicides applied to mesquite growing in eastern New Mexico and west Texas[1].

Herbicide	Application Date	Amount applied/tree	Canopy diameter(ft)	Soil type	Root Mortality (%) 1969	1970	1971	1973	1974	1975	1976
Dybar 25%	7/14/68	1 tbs.	3	silty	0	0					
Dybar 25%	7/19/68	1 tbs.[2]	3	sandy	32	50					
Dybar 25%	7/19/68	1 tbs.	3	sandy	50	61					
Dybar 25%	7/19/68	1 tbs.	3	unknown	50						
Dybar 25%	11/15/68	1 tbs.	1	unknown		88					
Dybar 25%	11/15/68	1 tsp.	1	unknown	88						
Dybar 25%	7/02/69	1 tbs.	3	sandy	0	43	43	43			
Dybar 25%	7/02/69	1 tbs.	3	rocky	4	73	74	82			
Dybar 25%	7/03/69	1 tbs.	3	unknown	21						
Dybar 25%	7/03/69	1 tbs.	3	unknown	4	22	22				
Dybar 25%	7/03/69	2 tbs.	3	unknown	4	34	34				
Dybar 25%	7/03/69	1 tbs.	3	silty	0	30	36	36			
Dybar 25%	7/03/69	1.5 tbs.	3	silty	0	38	46	46			
Dybar 25%	6/17/70	1 tbs.	3	sandy		44	54				
Dybar 25%	6/17/70	1 tbs.	3	unknown		51	51				
Dybar 25%	6/17/70	1 tbs.	3	sandy		44	54				
Dybar 25%	6/17/70	1 tbs.	3	unknown		51	51				
Dybar 25%	6/18/70	1 tbs.	3	sandy		41	48	57			
Dybar 25%	6/18/70	1 tbs.	3	silty		17	17	17			
Dybar 25%	6/18/70	1 tbs.	3	unknown		79	79	79			
Dybar 25%	6/18/70	1 tbs.	3	sandy		41	48	57			
Dybar 25%	6/18/70	1 tbs.	3	silty		17	17	17			
Dybar 25%	6/18/70	1 tbs.	3	unknown		79	79	79			
Dybar 25%	6/18/70	1 tbs.	3	unknown		79	79	79			
Tordon 10K	5/25/68	1 tbs.	3	sandy	0	0					
Tandex 10G	6/18/73	1 tbs.	2	unknown				0	0	38	
Tandex 10G	6/18/73	1 tbs.	2	unknown				0	0	38	
Tandex 10G	6/19/73	1 tbs.	2	unknown				0	37		78
Pramitol 5 PS	6/18/73	1 tbs.	1	unknown				0	0	20	
Pramitol 5 PS	6/19/73	1 tbs.	1	unknown				0	13		0
Hyvar XP	6/18/73	1 tbs.	1.5	unknown				0	0	29	
Hyvar XP	6/19/73	1 tbs.	1.5	unknown				0	11		54

1/ Data extracted from On Farm-On Ranch Demonstrations, 1967-1976, Brush and Weed Control Summary, Lea County, Department of Agricultural Services, New Mexico State University.

2/ 1 tsp. of herbicide approximates 1 gram of active ingredient.

Fisher, C. E. 1942. Mesquite eradication studies at Spur, Texas. The Cattleman 28(8):34-35, 37. (Asst. Soil Conservationist, Texas Agr. Exp. Sta.; research conducted at Spur, Texas).

F. W. Alexander, ranchman near Albany, tried spraying the trunks of trees with kerosene and found it to be quite effective for killing rough bark mesquite. A 2-inch paint brush was found satisfactory for applying the solution to the stumps. Considerable care was taken to remove the topwood well back to the main portion of the stump and to treat immediately all exposed sapwood. Hacking trees with an ax or treating only one of a number of limbs arising from the stump was not effective unless large amounts of poison was used.

On large rough bark trees, free from basal sprouts, girdling through the sapwood near the soil line and placing sodium arsenite in the groove gave complete control of sprouting. Kerosene, in most instances, whether applied to the trunks of trees or to stumps after the topwood was removed gave variable results. Kerosene was applied with a 3-gal compressed air sprayer fitted with a nozzle to emit a small jet-like stream, and sufficient amounts used to saturate the bark and soil around the base of the trees.

Removing the topwood and spraying the stumps or making applications to the lower 6, 12, 18, and 24-inch portions of the trunks did not affect the percentage of trees killed. The most important factor affecting regrowth was the amount of kerosene applied at the base of trees. More recent studies show that kerosene kills only at the point of application but does not penetrate into the root system. On young seedlings and rough bark trees free from sprouts, this treatment is effective and not too costly, but in the case of heavily branched second growth wood large amounts of kerosene are required.

Fisher, C. E. 1947. Present information on the mesquite problem. Texas Agr. Exp. Sta. Prog. Rep. 1056. 7p. (Agronomist, Texas. Agr. Exp. Sta.; research conducted at Spur, Texas).

Some factors affecting method of eradication:

1. All methods of killing mesquite depend upon destroying the dormant sprout buds located on the underground stem.

Fisher 1947 (con't.)

2. The great variation in growth forms and density of mesquite, variation in soils and size of unit to be cleared influence the method or methods to be selected.

3. Kerosene, diesel fuel and other cheap oils have been used successfully and economically to eradicate open stands of single to few-stemmed mesquite growing on soils that are porous and absorb oils to great depths. Many-stemmed mesquite growing on heavy soils have not been treated economically because large amounts of oils are required to reach all the buds on the underground stem. Failure to use sufficient amounts of oil to reach all the buds and large quantities of oils to be handled are the chief disadvantages of this method.

4. Sodium arsenite has been used economically and successfully to kill single-stemmed mesquite by treating frills cut near the soil level, and by removing the topwood of many-stemmed brush mesquite and poisoning the sapwood. It is highly effective on porous and heavy soils. The chief disadvantage of this method is the highly poisonous nature of sodium arsenite when handled carelessly.

5. Grubbing with power machinery is adapted to use by large operators or to custom work where the areas to be treated are large enough to justify the initial cost of equipment. The root cutter is better adapted to clearing open stands of trees while the pull cutter is better adapted to dense stands of brush mesquite.

6. Hand-grubbing is an effective method to remove scattering stands of mesquite trees and seedlings. It is usually too costly to clear moderate or dense stands of mesquite.

7. Removal of topwood of mesquite with a mobile tree saw, by fire or other means, does not eradicate mesquite. Such methods increase the brush problem unless the stumps are treated to prevent sprouting. Spraying chemicals on sprout growth of mesquite has not been developed sufficiently to be used successfully for practical eradication of mesquite.

8. Every type of mesquite eradication will require control of seedlings already established, those that come from seed on the ground, and from seed brought in by grazing animals and other means.

Fisher, C. E., C. H. Meadors, and R. Behrens. 1956. Some factors that influence the effectiveness of 2,4,5-trichlorophenoxyacetic acid in killing mesquite. Weeds 4:139-147. (Sup. and Tech., Texas. Agr. Exp. Sta., Spur, Texas and Assoc. Plant Physiologist, USDA-ARS; research conducted in south and west Texas).

Fisher et al. 1956 (con't.)

1. Effective and economical control of mesquite is dependent on translocation of a toxic amount of 2,4,5-T from the foliage to sprouting tissues of the crown.

2. Leaflet and field plot studies show that greatest translocation of 2,4,5-T occurs generally during a 50 to 90 day period after the first leaves emerge in the spring. This period is considered to be the most favorable time to treat mesquite with 2,4,5-T.

3. Maximum translocation of 2,4,5-T appears to take place when the total sugar content in the roots is building up at a rapid rate following the low level at the full leaf stage.

Herbel, C., F. Ares, and J. Bridges. 1958. Hand-grubbing mesquite in the semi-desert grassland. J. Range Manage. 11:267-270. (Research Agronomist and Range Conservationist, USDA-ARS, Jornada Exp. Range, and Rancher, Las Cruces, N. Mex.; research conducted on the Jornada Exp. Range, N. Mex.).

Hand-grubbing mesquite on 4,265 acres of typical semidesert grassland is reported. A method of laying out the grubbing area and a method of checking are explained in detail. An average of 0.593 man hr/acre was required for grubbing and flagging; an average of 0.043 man-hr/acre for the combination supervisor and clean-up man.
It is proposed that more attention be given to this economical method of controlling light stands of small mesquite plants to avoid further loss of valuable grassland.

Fisher, C. E., C. H. Meadors, R. Behrens, E. D. Robison, P. T. Marion, and H. L. Morton. 1959. Control of mesquite on grazing lands. Texas Agr. Exp. Sta. Bull. 935. Texas A&M University. College Station. 24p. (Superintendent of Substation No. 7, Spur, Texas, Tech., Plant Physiologist USDA-ARS, Asst. Agronomist, Assoc. Animal Husbandman, Research Agronomist USDA-ARS, respectively; research conducted at Spur, Texas).

Mesquite is an aggressive, deep-rooted, undesirable woody sprouting shrub that occurs on approximately 55 million acres of grazing lands in Texas.

Fisher et al. 1959 (con't.)

Economical control of mesquite on grazing lands depends largely on the selection of methods that will provide the greatest sustained benefits for the money expanded. Where mesquite thrives, no single method or practice will give effective and economical control under widely varying conditions. Good range and livestock management are essential to obtain maximum benefits from the control of mesquite. The chief value of controlling mesquite is to increase the density, vigor and production of palatable range forage species.

Some of the factors that influence the effectiveness and cost of controlling individual plants, in thin, open stands by hand or power grubbing, oiling with kerosene and diesel fuel and basal application of 2,4,5-T and soil application of monuron are discussed in this bulletin.

Factors that influence the effectiveness and cost of controlling moderate to dense stands by chaining and cabling, use of heavy-duty brush cutters, root plowing and aerial application of 2,4,5-T are enumerated.

The benefits of mesquite control include increase carrying capacity of the grazing lands, reduced cost of handling livestock and more efficient use of other range improvement practices.

Reinfestation of grazing lands by mesquite is aided by the dissemination of large numbers of viable seed by cattle, horses, sheep and rodents, the apparent lack of palatability of mesquite foliage to most grazing animals and the failure to maintain a heavy competitive cover of perennial grasses because of overgrazing, drouth, and other factors.

The values of mesquite are limited largely to utilization of the beans by grazing animals. Some use also is made of the wood for fuel, fence posts and source of roughage for feeding livestock. Additional uses included gum, preparation of charcoal and other special products.

Tschirley, F. H. 1962. Controlling mesquite with 2,4,5-T. University of Arizona. Coop. Ext. Ser. Folder 98-7M. (Range Conservationist, USDA-ARS; research conducted in southern Arizona).

The timing of a foliage application of 2,4,5-T is very important. The most dependable method of telling when mesquite is most susceptible to 2,4,5-T is by watching the development of the mesquite itself.

Tschirley 1962 (con't.)

Mesquite is most susceptible in the spring, when the leaves have reached full size, but are still succulent, and there is no more terminal elongation of new twigs. This condition will usually occur when flower development is complete and pods have started to elongate. The condition of the leaves is of principal importance, however and should be watched closely.

The period of maximum susceptibility will usually occur in May, but may occur in late April or early June. In some years, mesquite does not develop uniformily. If less than 75% of the trees are in the proper stage of development, spraying should be postponed until a more favorable year.

If mesquite cannot be treated at the proper time, it is better to err on the late than on the early side. Spraying as little as a week before the leaves are in an optimum stage of susceptbility will drastically reduce the effectiveness of 2,4,5-T.

Judging the best time to spray is not difficult, however, if the trees are observed closely. Simply remember the best results will be obtained if mesquite is sprayed when the leaves are full size and terminal elongation has stopped. Effectiveness of 2,4,5-T is gradually reduced as the season progresses and the leaves harden off.

Reynolds, H. G. and F. H. Tschirley. 1963. Mesquite control on southwestern rangeland. U.S. Dep. Agr. Leaflet No. 421. 8p. (Wildlife Research Biologist USDA-FS, and Range Conservationist USDA-ARS, Tucson, Arizona; research conducted in southern Arizona).

Robison, E. D. 1963. Chemical brush control in west Texas. Texas Agr. Prog. 9(3):3-5. (Asst. Range Scientist, Spur, Texas; research conducted at Spur, Texas).

Observations over several years of research at the Spur station suggest the following precautions can, in time, result in higher degrees of mesquite control:

1. Aerial applications are not advisable when adverse weather conditions limit the growth of mesquite. Sparse or irregular foliage development usually reduces the effectiveness of the herbicide application.

Robison 1963 (con't.)

2. Spray results will be better when applications are made under relatively low wind speeds, with moderate temperatures and high relative humidities.

3. Generally, kills will be better when spraying is done during a year of good moisture which follows a year or more of low rainfall.

4. Generally, a higher percentage of trees will be killed on areas with sandy to mixed soils than on areas with heavy, tight soils; kills will be greater on upland slopes than on bottomland sites.

5. Mesquite seedlings and trees of medium size, 2 to 4 inches in diameter and 6 to 12 ft in height, normally are easier to kill than large, old trees.

6. Aerial retreatment is equally effective on regrowth in areas previously treated by aerial application or other means, such as chaining or bulldozing.

7. When retreating, results will be more effective if mesquite growth is allowed to reach a height exceeding 4 ft.

8. Proper mixing, loading and application procedures should be observed at all times to insure adequate coverage and concentration of the spray material.

When the mesquite stand is small, scattered and just invading, individual plant treatments with a solution of 2,4,5-T in diesel oil should be used. This solution of 8 lb 2,4,5-T in 100 gal diesel oil applied to the base of each tree, to the point of runoff, will give highly effective results. Preventive maintenance will save money and much effort later.

Muzik, T. J. and W. G. Mauldin. 1964. Influence of environment on the response of plants to herbicides. Weeds 12:142-145. (Washington Agr. Exp. Sta., Pullman, Washington; greenhouse study conducted in Pullman, Washington).

Absoroption and translocation in both leaves and roots is less under low temperatures. Seasonal response of wheat to 2,4-D is conditioned by the stage of growth as well as environment. The response of wheat and downy bromegrass to triazine herbicides is seasonal, whereas the response to carbamate herbicides appears to be influenced by local environmental conditions at time of spraying. Physiological condition of fiddleneck is more important than age, i.e., plants in the rosette stage were always far more sensitive than bolting plants of the same age. Sensitivity to 2,4-D was greater at 26 C than at 10 C or 5 C

Muzik and Mauldin 1964 (con't.)

at all stages of growth. Application of certain metabolites, especially thiamin, increased the sensitivity of fiddleneck to 2,4-D at low temperatures.

Greer, H. A. L. 1967. Mesquite control in Oklahoma. Oklahoma Ext. Fact. Science Serving Agr. No. 2760:2760-2760.3. Oklahoma State Univ., Stillwater. (Extension Weed Control Specialist, Coop. Ext. Service, Okla. State Univ., Stillwater, Okla.; research conducted in Oklahoma).

Davis, F. S., R. W. Bovey, and M. G. Merkle. 1968. Effect of paraquat and 2,4,5-T on the uptake and transport of picloram in woody plants. Weed Sci. 16:336-339. (Plant Physiologist and Agronomist, USDA-ARS, College Station, Texas; greenhouse study conducted at College Station, Texas).

We studied the uptake and transport of 4-amino-3,5,6-trichloropicolinic acid (picloram) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) alone and in combination and in the presence of 1,1'-dimethyl-4,4'-bipyridinium salt (paraquat) by honey mesquite, huisache, and bean. Paraquat reduced transport of picloram by mesquite, huisache, and bean. Paraquat increased uptake of picloram by yaupon but did not affect transport. The uptake and transport of 2,4,5-T by mesquite decreased in the presence of picloram, but the uptake and transport of picloram increased in the presence of 2,4,5-T. Increasing ratios of 2,4,5-T: picloram up to 16:1 continued to increased uptake and transport of picloram; the inverse effect occurred for 2,4,5-T when picloram:2,4,5-T ratios were increased.

Davis, F. S., M. G. Merkle, and R. W. Bovey. 1968. Effect of moisture stress on the absorption and transport of herbicides in woody plants. Bot. Gaz. 129:183-189. (Research Plant Physiologist and Research Agronomist, USDA-ARS, College Station, Texas; greenhouse study conducted at College Station, Texas).

Davis et al. 1968 (con't.)

Absorption by foliage and distribution of picloram (4-amino-3,5,6-trichloropicolinic acid) and 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) as affected by moisture stress were studied in mesquite and winged elm under a controlled environment. Gas chromatographic assay measured the movement of both herbicides into untreated portions of the plant.

Mesquite absorbed picloram more rapidly and extensively than 2,4,5-T. After 4 hr the apex contained both herbicides, but only picloram was present in the roots. After 24 hr the apex and roots contained more picloram than 2,4,5-T. The phloem-cortex accumulated greater quantities of picloram than the xylem-pith. After 90 hr herbicide concentrations in most tissues were unchanged or higher than after 24 hr. Mesquite and winged elm transported markedly different amounts of 2,4,5-T.

Moisture stress reduced foliar uptake of picloram in mesquite but not in winged elm. Moisture stress did not affect absorption of 2,4,5-T.

Stress reduced transport of herbicides differently in the two species, but reduced transport generally paralleled retarded growth. Moisture stress sufficient in slow growth markedly reduced transport of both herbicides into untreated tissues. The largest reductions in transport occurred at moderate stresses or where extensive movement occurred under no stress.

Meadors, C. H., C. E. Fisher, E. D. Robison, and B. T. Cross. 1970.

Field testing of a new method for aerial application of herbicides to honey mesquite. Texas Agr. Exp. Sta. Prog. Rep. PR-2827, p. 93-95. _In_, Brush Research in Texas. Cons. Prog. Rep. 2801-2828. Texas A&M University, College Station. (Research Assoc., Professor in charge of brush control, Research Assoc., and Tech., Texas A&M Univ.; research conducted in King and Dickens Counties, Texas).

New Mexico Inter-Agency Range Committee. 1970. Control of shinnery oak, mesquite and creosotebush in New Mexico. USDA-ARS. Las Cruces, New Mexico. Report No. 4. 33p. (Credentials unknown).

Begin spraying after full lead development and the leaves have turned to a dark green color, terminal growth is complete, and the plants are in full flower until the seed pods have elongated but have not started to fill. Usually these conditions occur between June 1 and June 15. The period for spraying to get satisfactor kills is generally 2 to 3 weeks.

Dahl, B. E. and J. P. Goen. 1971. Site characteristics and phenological development of mesquite, p. 5-7. In, Ninth Ranch Management Conference, Proc. ICASALS Contribution No. 101, Texas Tech Univ., Lubbock. (Prof. and Research Assoc., Dep. of Range and Wildlife Manage., Texas Tech University, Lubbock; research conducted near Post, Texas).

Soil temperature was the dominant influence affecting root kills with 2,4,5-T in this study. Depth of temperature measurements anywhere between 12 and 24 inches were about equally effective with measurement at 12 inches best. In no case where soil temperature was 74 F or lower, did mesquite root kills exceed 12%. This is an overriding factor affecting the results of all other environmental characteristics measured. By this we mean, that when soil temperatures were below 75 F, regardless of soil moisture, plant phenological development, air temperature, time of day, etc., essentially no root kills were obtained with 2,4,5-T.

Abundance of flowers on a tree was secondary to soil temperature in determining root kills, i.e. the more abundant the flowers the poorer the root kills. Trees loaded with flowers were regarded as having 100% flowers, those with no flowers as 0%, the intermediate degrees of flowering rated subjectively on a sliding scale from 0-100%. However, the Post-Montgomery Ranch study indicated that the warmer the site, the higher the percentage flowers so we have some confounding of the effect of flower abundance and soil temperature that is not readily separable at this time. Mesquite root kills never exceeded 12% on those sites where the flower abundance values averaged greater

Dahl and Goen 1971 (con't.)

than 17%. Therefore, as in the 1968-69 study, soil temperature and stage of growth are dominant influences affecting mesquite appears now even more influential than it did in the 1968-69 pilot study.

If we study only those sites with soil temperature about 74F some interesting relationships appear. Soil moisture becomes quite important, but in a negative way. The lower the soil water content the better the mesquite kills, which is not what we thought in the past. Apparently, dry soils warm up faster and to a higher temperature than wet ones, hence the negative relationship. In fact, our highest kills occurred on sites with soils at the wilting point, i.e. with no usable water available to the plant in the top 2 ft of soil. Fig. 1 shows that soil temperatures in a densely shaded wet site in 1968 never reached 74 F and it only did so when the soil moisture was more depleted as during the drought of 1971. This suggests that droughty conditions during the spring and early summer could possibly increase mesquite kills with 2,4,5-T on sites that, with adequate spring and summer precipitation, are normally wet and cold.

Dahl, B. E., R. B. Wadley, M. R. George and J. L. Talbot. 1971. Influence of site on mesquite mortality from 2,4,5-T. J. Range Manage. 24:210-215. (Associate Professor, Research Associate, and Graduate Research Assistants, Dep. of Range and Wildlife Manage., Texas Tech Univ., Lubbock, Texas; research conducted in Texas).

Soil temperature at the 18-inch depth was the most important factor affecting response of honey mesquite to 2,4,5-T application. Temperatures at this depth in the high 60's F or low 70's F resulted in no mesquite kills with the best results obtained if temperatures were over 80 F. Phenological development was essentially as important with plants having mature leaves and seed pods being easiest to kill. Trees with small and blooming spikes and those without flowers or pods were hardes to kill with 2,4,5-T. Other variables usually considered important, such as soil moisture, were important only in combination with other variables. Mesquite trees growing on upland and sandy sites are apparently more susceptible to 2,4,5-T largely because the soil is usually several degrees F warmer than bottomland and clay sites.

Meyer, R. E., R. W. Bovey, W. T. McKelvy, and T. E. Riley. 1972. Influence of plant growth stage and environmental factors on the response of honey mesquite to herbicides. Texas Agr. Exp. Sta. B-1127. Texas A&M University. College Station. 19p. (Plant Physiologist, Research Agronomist, Biological Research Tech. and Agr. Research Tech. USDA-ARS, Tex. Agr. Exp. Sta.; research conducted near Bryan, Texas).

Honey mesquite (*Prosopis juliflora* (Swartz) DC. var. *glandulosa* (Torr.) Cockerell) plants 4 to 6 ft tall grown on an uplant, clay loam site near Bryan, Texas, were sprayed with three herbicides at 14 dates during 1969 and 1970. Herbicide treatments consisted of 0.5 to 1 lb/acre rates of the potassium salt of 4-amino-3,5,6-trichloropicolinic acid (picloram) and the butoxyethanol ester of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) alone and in 1:1 mixtures. Mixtures of the two herbicides as the triethylamine salts were applied at six dates at application rates of 0.25 + 0.25 and 0.5 + 0.5 lb/acre.

Plant factors measured were new stem elongation growth, transectional stem dimensions, upward dye movement rate in the xylem, total available stem carbohydrates and leaf moisture stress. Environmental factors included were air temperature, percent relative humidity, soil temperature, soil moisture, rainfall and total daily solar radiation.

Picloram and a mixture of picloram + 2,4,5-T caused 53 and 56, and 62 and 63% defoliation 1 year after treatment at the 0.5 and 1 lb/acre rates, respectively, whereas 2,4,5-T cuased 44 and 48% defoliation. Picloram at 0.5 and 1 lb/acre and picloram + 2,4,5-T at the 0.25 + 0.25- and 0.5 + 0.5-lb/acre rates killed 11 and 12% and 23 and 27% of the plants, whereas 2,4,5-T alone killed only 2% of the plants at both rates. Control by the triethylamine salts of picloram + 2,4,5-T was equal to that of the mixture of potassium salt of picloram + the 2,4,5-T ester.

Meyer et al. 1972 (con't.)

Most effective control of honey mesquite occurred from treatments applied between April 30 and July 6. Plant characteristics most closely associated with control were widest translocating phloem thickness, most rapid rate of new xylem ring radial growth and lowest predawn leaf moisture stress. Environmental variables most closely associated with honey mesquite control were lower maximum air temperatures of 77 to 96 F 1 week before treatment, maximum soil temperatures at 63 to 79 F at a depth of 3 ft 1 week before treatment and decreasing percent soil moisture from 25 to 18% at a depth of 2 to 3 ft 1 week before treatment.

The higher percent defoliation and percent dead plant ratings were most closely associated in order of effectiveness with herbicidal treatments of picloram mixture of picloram + 2,4,5-T, and 2,4,5-T. The defoliations correlation were higher than those for the percent of dead plants. Generally, thickness of translocating phloem, rate of upward dye movement in the xylem, lower minimum relative humidity, high soil moisture and higher rainfall before spraying were directly correlated with higher plant control, while measurements of new xylem thickness, air temperature, maximum relative humidity before spraying, maximum soil temperature, rainfall after spraying and leaf moisture stress were inversely correlated with high percent control by herbicide treatments.

Simple correlations of environmental data showed two groups of variables. Air and soil temperatures were directly correlated. Percent relative humidity, percent soil moisture and rainfall were directly correlated, but they were inversely correlated with air and soil temperature, rainfall after spraying and leaf moisture stress were inversely correlated with high percent control by herbicide treatments.

Regression equations were developed for estimating percent defoliation and percent dead plants for both rates of picloram salt + 2,4,5-T ester and 2,4,5-T at all 14 dates of application.

Moisture stress of the honey mesquite leaves varied from a low level in the morning to the highest level at midday to a low level again at night. The stress values at night increased slightly, and the maximum level during the day remained longer as the summer progressed.

Within 2 or 3 days after herbicide application, leaves of treated plants had a lower moisture stress level during the day than the untreated leaves. By the fourth day, treated leaves began dying, so they became more stressed than untreated leaves. Leaves sprayed with picloram and a mixture of picloram + 2,4,5-T tended to turn brown and remain on the plants; those sprayed with 2,4,5-T tended to turn yellow and lose their leaflets from the rachises before either dying on the plant or abscising.

Meyer, R. E., R. W. Bovey, T. E. Riley, and W. T. McKelvy. 1972. Leaf removal interval effect after sprays to woody plants. Weed Sci. 20:498-501. (Plant Physiologist, Research Agronomist, Agr. Research Tech., and Biol. Aid, USDA-ARS, College Station, Texas; greenhouse study conducted at College Station, Texas).

Greenhouse grown honey mesquite (*Prosopis juliflora* (Swartz) D.C. var. *glandulosa* (Torr.) Cockerell), huisache (*Acacia farnesiana* (L.) Willd.), and whitebrush (*Aloysia lycioides* Cham.) and field grown honey mesquite, huisache, whitebrush, live oak (*Quercus virginiana* Mill.), Arizona ash (*Fraxinus velutina* Torr.), and winged elm (*Ulmus alata* Michx.) were defoliated at several intervals following spray treatments with 4-amino-3,5,6-trichloropicolinic acid (picloram), 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), or ((4-chloro-o-tolyl)oxy)acetic acid (MCPA). The time required by leaves to be retained on the plant after spraying to give maximum canopy reduction or death of plants varied among species. In most species, however, herbicide absorption and transport were complete within a 4-day period or less as compared to undefoliated treated plants.

Hoffman, G. O. 1973a. Ground application methods to reduce woody plant densities with 2,4,5-T. Texas A&M Univ. Ext. Cir. RM 3-1. (Ext. Range Brush and Weed Control Specialist, Texas A&M Univ. System; research conducted throughout Texas).

Kind of Brush	Size of Brush	Method of Application	Season of Application	Chemical Mixture	Kind of Equipment Needed
Sprouts and seedlings	Sprouts at least 4 yr old and 6 ft tall or less	Foliage spray--complete and thorough wetting of foliage	April, May, June--adequate soil moisture and good growth conditions	3 lb/100 gal water plus 2 to 16 oz surfactant	Power sprayer of knapsack hand sprayer, 40 lb of pressure or less
Seedlings	6 mos or less fully leafed	Foliage spray--broadcast complete coverage	April, May, June--adequate soil moisture and good growth conditions	2 lb/acre mixed in 20 to 30 gal water plus 2 to 16 oz surfactant/100 gal solution	Broadcast spray. Boom or boomless nozzle with PSI 40 lb. or less.

Hoffman. G. O. 1973b. Brush management with chemicals. Aerial broadcast application. Texas A&M Univ. Ext. Circ. RM 3-1. (Ext. Range Brush and Weed Control Specialist, Texas A&M Univ. System; research conducted throughout Texas).

Kind of Brush	Size of Brush	Method of Application	Season of Application	Chemical Mixture
Mesquite tree type	All trees or sprouts at least 4 ft tall or more and 4-6 years old with dense foliage	Foliage, air spray-swath widths adequate to insure complete coverage for effective control	Spring, water good growth conditions, 40 to 90 days after first green growth appears at the bud with dark green foliage and soil temperatures of over 70 F to begin spray operations	2,4,5-T at ½ lb/acre in west Texas nad 1 lb/acre in other areas of Texas. 1 gal diesel oil and water to make 4 to 5 gal/acre solution. Picloram + 2,4,5-T at ½ lb/acre in west Texas. In other areas of Texas 1 lb/acre. Use 1 gal diesel oil+special emulsifier and water to make 4 to 5 gal/acre solution for both rates. Dicamba+2,4,5-T at ½ lb/acre in west Texas and 1 lb/acre in other areas of Texas. Any time heavy infestation of ragweed, use dicamba +2,4,5-T mixture at either strength instead of straight 2,4,5-T.
Creeping type	All growth forms --original and sprouts with dense foliage	Foliage air spray—swath widths to insure complete coverage for effective control. Usually 2 to 3 applications are necessary in successive years, limited to South Texas Plains	Spring, under good growth conditions, 40 to 90 days after first green growth appears at the bud	2,4,5-T at 2/3 lb/acre in 1 gal diesel oil and water to make 5 gal/acre solution. Use picloram + 2,4,5-T at 2/3-1 lb/acre for second and third sprayings if site contains cactus, huisache, granjeno, twisted acacia, or other susceptible mixed-brush specie.

Hollingsworth, E. B. 1973. Root plow herbicide application. Agrichemical Age. September:8-9. (Botanist, Southern Weed Science Research Lab., Stonesville, Miss.; location where research conducted unknown).

Hull, H. M., H. L. Morton, and R. D. Martin. 1973. Translocation of picloram in velvet mesquite seedlings as influenced by humidity and type of carrier. Weed Sci. Soc. Amer., Proc. 13:65-66. (Abstr.). (USDA-ARS, Tucson, Ariz.; greenhouse study conducted in Tucson, Ariz.).

Mesquite seedlings were grown to an age of 8 weeks on a 16 hr photoperiod (1,200 ft-c) at photo/nyctotemperatures of 33/28 C. During this period and also post treatment, relative humidity was maintained at either 28 to 34% (low) or 76 to 82% (high). The potassium salt of picloram (1,000 ppmw ae), along with sorbitan monolaurate (0.5% v/v), was applied in various carriers to the upper surface of leaves located on the central third of the stem, at a rate of 20 µl per leaf. Contact injury, formative effect, stem dieback, and repression of growth and shoot and root weight were recorded at various intervals from 5 days to 4 weeks after treatment.

Most responses were minimal when the picloram was carried in water on a 15% emulsion of isoparaffinic oil in water. An aqueous carrier containing 25% glycerol increased contact injury, although most other responses were not greatly enhanced. When the picloram was carried in a mixture of 50% dimethylsulfoxide (DMSO), 25% glycerol, 15% isoparaffinic oil, and 10% water, all responses were significantly enhanced. No significant differences in most response categories could be ascribed to humidity, although there was a slightly greater growth repression and dieback in plants treated under low humidity conditions.

Gas chromatographic analysis of extracts from various tissues harvested 48 hr after treatment showed that the quantity of picloram in the stem and leaves, both above and below the treated leaves and also in the apical region, was significantly greater with the DMSO carrier complex than with any of the other carriers. Basipetal transport of picloram with all carriers was greater in high humidity than in low. Transport into the roots was slight and variable, and was not significantly enhanced with DMSO.

Scifres, C. J., R. W. Bovey, C. E. Fisher, and J. R. Baur. 1973. Chemical control of mesquite, p. 24-32. In, C. J. Scifres (Chm.), Mesquite. Research Monogr. No. 1 Texas A&M University. College Station, Tex. (Assoc. Prof., Texas Agr. Exp. Sta., Dep. of Range Sci., Agronomist, USDA-ARS, Dep. of Range Sci., Prof., Tex. Agr. Exp. Sta., Lubbock, Plant Physiologist USDA-ARS, Dep. of Range Sci.; research conducted throughout Texas).

The advent of the highly selective phenoxyacetic acid herbicides, especially 2,4,5-T, revolutionized the approach to mesquite control. Since its introduction, intensified research has been directed toward developing safer and more effective herbicides and application techniques.

Regardless of the herbicide, additive, carrier or application technique, foliar applications are presently most feasible for control of dense infestations of mesquite. Aerial-application of 2,4,5-T at about 0.5 lb/acre is the most widely used method. Soil-applied, substituted urea herbicides such as monuron and fenuron are effective, but dicamba granules and picloram pellets have proved ineffective.

Mesquite is most susceptible to foliar sprays at 40 to 90 days after first leaves emerge in the spring. Any environmental factor which limits growth and development limits effectiveness of the sprays. The leaves must be fully developed and turning dark green but not too heavily cutinized to allow entry of the herbicides from the leaves through the stems to the crown and roots. These conditions generally occur from mid-May to July 1. The time of movement of greatest amounts of food materials from leaves coincides closely with maximum movement of herbicides in mesquite. Maximum canopy development and area are undoubtedly prime requisites for optimum activity of foliar applied herbicides.

Although the addition of picloram to 2,4,5-T usually increases the number of mesquite plants killed, effectiveness of the combination is probably regulated by the same factors that influence the activity of 2,4,5-T alone. The addition of picloram to 2,4,5-T also has usually increased the range of associated undesirable species controlled. Although the combination of dicamba with 2,4,5-T has not proved synergistic, indications are that several associated weed species are more susceptible to the mixture than to 2,4,5-T alone.

Many carriers and additives have been tested for the application of herbicides to mesquite. None have proved consistently superior to a 1:3 or 1:4 diesel oil:water emulsion. However, some recent experiments indicate improved drift control with certain oil carriers over that of the standard emulsion.

Sosebee, R. E., B. E. Dahl, and J. P. Goen. 1973. Factors affecting mesquite control with Tordon 225 Mixture. J. Range Manage. 26:369-371. (Asst. Prof., Assoc. Prof., and Research Assoc., Dep. of Range and Wildlife Manage., Texas Tech Univ., Lubbock; research conducted in the Rolling Plains of Texas).

The influence of various site characteristics was studied for Tordon 225 Mixture effectiveness in honey mesquite control in the Rolling Plains of Texas. Tordon 225 Mixture was commercially applied in 1970 at 0.5 lb a.e./acre under an experimental label for Texas. Generally, soil temperature (18-inch depth) above 75 F, relatively low soil water content (0 to 6-inch depth), and tree height (less than 8 ft) were most influential in the root mortalities obtained in this study.

Goen, J. P. 1975. Influence of environment on mesquite phenology. M.S. Thesis. Texas Tech Univ., Lubbock. 95p. (Research Assoc., Dep. Range and Wildlife Manage., Texas Tech Univ., Lubbock; research conducted in the Rolling Plains of Texas).

Bud emergence in mesquite trees was highly correlated (r=0.95) with minimum air temperature following March 1, i.e., after daylength was about 11½ hours. Following March 1 when the minimum air temperature dropped to approximately 0 C for 5 to 7 consecutive days, buds would begin to emerge 2 to 3 weeks later. Soil temperature and maximum or minimum air temperature had little influence on bud emergence.

West Texas notoriously has cold spells that are sufficiently severe to kill exotic fruit, such as peach (*Prunus perscia*) and apricot (*Prunus armeniaca*) blossoms. Mesquite is the major endemic woody species in the area, and it has apparently survived the rigors of the spring climate rather than being killed by late cold periods. Mesquite requires a vigorous "cold spell", i.e., several days of near freezing temperature minimums to stimulate its "leafing-out" process. Thus, it is seldom fooled by late winter and early spring period of warm weather.

Topographic features caused major differences in soil temperature on the same date. Soils of densely shaded draws and drainage areas did not warm up as rapidly as sparsely populated upland and sandy sites. Therefore, when mesquite trees were apparently phenologically susceptible to herbicides, the soil of some sites were still too cool for consistent mesquite root mortality from growth regulating herbicides.

Goen 1975 (con't.)

Along the topographic effects, the texture of the soil contributed to the variation in date of site warm up. Heavy textured clays with a large water holding capacity warmed up slower than the loamy and sandy textured soils. Also, the more dense the mesquite, the slower the soils warmed up because of the shading of the soil surface.

Reproductive organs produced on trees of all sites were numerous up to the yellow flower stage of development, then apparently a combination of factors such as wind, rain, hail and insects caused severe losses that resulted in either no mature pods being produced or only a few pods that reached maturity. A few trees produced a proportionately large number of pods all 4 years of the study, whereas some trees produced no pods at all during the study.

Some researchers have reported multiple crops of inflorescence during the same year, but this was seldom observed during this study.

Because research with chemical control of mesquite has long indicated topographic differences as restricting mesquite kills (Fisher et al., 1959) and because Dahl et al. (1971) and Wilson et al. (1975) found that variations in soil temperature and number of flowers and fruits per tree effected mesquite root kills, this study was designed to evaluate the role of topography, soil texture, soil moisture, and climate on mesquite phenology and size of fruit crop. Thus, the study should provide a better basis for timing application and evaluating results of growth regulating herbicides. Anticipated major differences in date of bud break and in potential fruiting load did not materialize. Thus, the major influence of site on mesquite is mostly from the influence of temperature on physiological processes in the root that can affect plant response to herbicides. Thus, land managers desiring to control mesquite with 2,4,5-trichlorophenoxyacetic acid or Tordon 225 Mixture should inventory their infested rangeland and apply the herbicide when conditions are optimum for the site situation most needing mesquite control.

Haagsma, T. 1975. DOWCO 233 herbicide--a possible new tool in vegetation management. Down to Earth 30(4):22-24. (Ag. Organics Dep. Dow Chemical, USA; location where research conducted unknown).

Hoffman. G. O. 1975. Control and management of mesquite on rangeland. Texas Agr. Ext. Service. MP-386. Texas A&M Univ., College Station. 15p. (Ext. Range Brush and Weed Control Spec.; research conducted in Texas).

Hoffman 1975 (con't.)

Mesquite is a natural component of most rangeland vegetation in Texas. Mesquite, honey, western honey, velvet and creeping all grow in Texas. Honey mesquite is the most widespread, with creeping growing in the Frio-Nueces river watersheds and with velvet and western honey occurring west of the Pecos River. In this publication, honey, western honey and velvet mesquite will all be referred to as mesquite.

Mismanagement of grazing lands, protection from fire, drouth, heavy concentration of livestock, fencing and a combination of these factors have favored encroachment of mesquite. It is a problem on some 56 million acres of Texas rangelands. Grasslands that are heavily infested with mesquite often produce inadequate amounts of desirable forage for economic livestock production and provide poor habitat for wildlife.

Ecologically, mesquite is a strong competitor for water and plant nutrients; it is a profuse seed producer; it is a prolific sprouter; and it is not a preferred food item in the diet of any animal except at specific times during the year. At time, mesquite beans can even become toxic to grazing animals. However, mesquite has been utilized as a source of food for humans, animals and birds. It also has been used for fuel, medicine, bleaching agent, charcoal, bowling pins, spurs, building materials, fence posts, gun stocks and golf clubs.

It is likely that every owner or manager of rangelands would like to eradicate or selectively control mesquite with a single treatment and forget the problem. However, mesquite control is a complex problem. In northern areas of Texas, mesquite may be the only problem species while in the southern part of the state, mesquite may be only one of many species to be treated. In mixed stands of woody plants where mesquite is controlled the development of resistant species may rapidly become the major brush problem.

Ueckert, D. N. 1975. Response of honey mesquite to method of top removal. J. Range Manage. 28:233-234. (Assoc. Prof., Dep. Range and Wildlife Manage., Texas Tech Univ., Lubbock; research conducted in the Rolling Plains of Texas).

Shredding stimulates regrowth of honey mesquite in the Rolling Plains of Texas compared to spraying the foliage with 2,4,5-T, burning, and basal application of diesel + 2,4,5-T. Regrowth of shredded trees was 4.7 times greater than that of trees sprayed with 2,4,5-T and 6.6 times greater than that of trees previously burned. This information should aid ranchers in choosing initial control practices for honey mesquite which will be necessary.

Ulich, W. L. and F. Turley. 1976. Front tractor mounted mesquite shredder-sprayer, p. 28. In, R. E. Sosebee and H. A. Wright (ed.), Noxious Brush and Weed Control Research Highlights. Vol. 7. (Prof., Dep. of Agr. Engineering and Research Assoc., Dep. Range and Wildlife Manage., Texas Tech Univ., Lubbock; location where research conducted unknown).

A hydraulic horizontal shredder constructed for mounting on the front of a 2-wheel-drive farm tractor was purchased and modified for brush control research at Texas Tech University. The shredder consists of two hydraulic motor powered cutter heads, each containing two off-set swinging knives. Hydraulic power is generated by a two-unit H&P P-T-O connected pump. Each cutter head may be operated in either direction by control valves mounted within reach of the tractor operator. A standard lift and positioner provides a cutting height from 0.5 inch to 3 ft above ground surface. Heads have a 45 degree controlled lift angle for operating on rolling terrain.

The machine also includes a front mounted automatic trip stump sprayer. Spray pressure is derived from a gear pump driven by a P-T-O pulley. A series of rubber pad trippers trip spring loaded valves to enable two rows of spray nozzles to spray stumps from which trunks have been cut by shredder heads. Sprayer unit is mounted behind shredder heads. Sprayer unit is mounted behind shredder head and in front of tractor front wheels.

The dual unit cuts and sprays a swath 9 ft 8 inches wide and has been field tested at forward speeds of 3 to 4 mph in medium mesquite infestations. In initial tests, trunks have been cut up to 10.5 inches in diameter. Trials indicate a coverage of 3 to 4 acres/hr in light to medium infestations. The sprayer unit appeared to operate satisfactorily mechanically, however, the resultant stump kill will not be available until a later date.

Preliminary data indicates this method of cutting mesquite and spraying stumps to be an economical mechanical method of surface mesquite removal and possibly regrowth control. Additional data such as field efficiencies, machine wear, machine down time, and regrowth control in various degrees of infestations will be required for final evaluation and cost determinations.

Meyer, R. E. 1977. Seasonal response of honey mesquite to herbicides. Texas Agr. Exp. Sta. B-1174. Texas A&M Univ. College Station, 14p. (Plant Physiologist, USDA-ARS, Tex. Agr. Exp. Sta., Dep. Range Sci.; research conducted near Millican, Texas).

Honey mesquite was sprayed with 0.56 + 0.56 kilogram per hectare (kg/ha) of picloram (4-amino-3,4,5-trichloropicolinic acid) + 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) or 1.12 kg/ha of 2,4,5-T at 22 dates during 1972 and 1973. Honey mesquite was most effectively controlled during late April, May and June. With this and another 2-year study, at the 17 best dates, picloram + 2,4,5-T alone reduced the canopy 92% and killed 59% of the plants, while 2,4,5-T was less effective reducing the canopy 66% and killing 5% of the plants. Over 36 dates from March 24 to October 9, during a 4-year period, percent honey mesquite canopy reduction was directly correlated with total phloem thickness, rate of new xylem ring radial growth, and rate of upward methylene dye movement in the xylem, and was inversely correlated with minimum leaf moisture stress. In simple regression equations, for all 36 dates from March 24 to October 9, rate of new xylem radial growth gave the best predictive equation. For 33 dates between April 29 and August 31, the best equation contained soil moisture level at a depth of 91 centimeters (cm), minimum leaf moisture stress, or rate of upward methylene blue dye movement. At 13 increasingly effective early season dates, control was best predicted by soil temperature at a depth of 91 cm. At 22 decreasingly effective summer dates, control was best predicted by minimum leaf moisture stress for percent canopy reduction by both herbicides and by rate of new xylem ring radial growth for percent plants killed by picloram + 2,4,5-T. Rate of new xylem ring radial growth and thickness of translocating phloem were the factors appearing most often in the equations.

Boyd, W. E., R. E. Sosebee, and E. B. Herndon. 1978. Shredding and spraying honey mesquite. J. Range Manage. 31:230-233. (Grad. Research Asst. and Assoc. Prof., Dep. Range and Wildlife Manage, Texas Tech Univ., and Research Assoc. Dep. of Range and Wildlife Manage., Texas Tech Univ., Quanah, Texas; research conducted in the Rolling Plains of Texas).

Shredding and spraying honey mesquite are effective methods of control. Overall, the highest percent root mortalities were obtained from treatments applied in May, but shredding and spraying were effective when applied during other months of the year, even during the fall and winter. Root mortalities obtained from aqueous solutions

Boyd et al. 1978 (con't.)

of either 2,4,5-T amine or picloram plus 2,4,5-T during the year were dependent upon water content and temperature in the upper 15 cm of the soil (2,4,5-T, $\underline{R}$=0.88; picloram plus 2,4,5-T, $\underline{R}$=0.82). Average root mortalities for all months were consistently the greatest from picloram plus 2,4,5-T (57%), followed by dicamba (34%) and dicamba plus 2,4,5-T (31%). Root mortalities obtained from 2,4,5-T amine (26%) and 2,4,5-T ester (25%) were the lowest obtained in the study.

Sosebee, R. E., B. E. Dahl, J. P. Goen and C. S. Brumley. 1978. Discriminate use of the mist blower, p. 17. In, R. E. Sosebee and H. A. Wright (ed.), Noxious Brush and Weed Control Research Highlights. Vol. 7. (Assoc. Prof., Prof., Research Assoc., and Research Asst., Dep. Range and Wildlife Manage., Texas Tech Univ., Lubbock; research conducted near Post, Texas).

The mist blower that was developed for control of shin oak in Oklahoma has been used in other areas of the Southwest to control noxious brush. However, indiscriminate use has resulted in crop damage and lawsuits for well-meaning ranchers. The mist blower has potential for use in Far West Texas rangelands away from susceptible cultivated crops. Therefore, investigations are continuing into how to more safely use the mist blower.

In 1975, various treatments involving 2,4,5-T, Tordon 225, Banvel plus 2,4-D, dicamba, and Pennamine D were applied to regrowth mesquite approximately 3 to 5 ft tall. Treatments included only the amine formulation of all herbicides. Application rates were 1/4 to 1/8 lb a.e./acre. Distance between treatments was 200 ft to avoid spray drift across plots scheduled to be treated with different herbicides. Distribution of the herbicides and mesquite defoliation was dependent upon wind velocity. Adequate distribution of the herbicide was not obtained at wind velocities less than 12 mph; therefore, the mesquite was not defoliated farther than about 50 ft from the path of the sprayer. However,with wind velocities up to 20 mph, defoliation occurred on mesquite growing 75 to 100 ft on the leeward side of the sprayer.

In July, 1976, similar treatments were applied to regrowth mesquite 4 to 5 ft tall. Cotton seedlings grown in pots within a greenhouse were placed at various intervals perpendicular to the mist blower path during herbicide application to determine distance of herbicide drift. Potted cotton plants were placed at 10, 25, 50, 75, 100, 150, 200 and 250 ft from the mist blower path. The cotton plants were distributed throughout the mesquite prior to spraying and collected after herbicide application. They were returned to the greenhouse

Sosebee et al. 1978 (con't.)

and grown for observation of herbicide damage. Evaluations of herbicide damage were made biweekly after spraying. Two months after spraying, final herbicide damage evaluations were made. Preliminary results indicate that although mesquite growing at distances further than 100 ft from the mist blower path may not be defoliated, potted cotton seedlings may be damaged. Some of the cotton plants growing 250 ft downwind from the mist blower path were damaged or killed when sprayed with either 2,4,5-T or Tordon 225 when the wind velocities were 12 to 15 mph. Further evaluation of physical drift will be necessary before distance tolerances can be accurately determined.

Sosebee, R. E., W. E. Boyd, and C. S. Brumley. 1979. Broom snakeweed control with tebuthiuron. J. Range Manage. (*In Press*). (Assoc. Prof., Graduate Research Asst., and Research Assoc., Dep. of Range and Wildlife Manage., Texas Tech Univ., Lubbock; research conducted in West Texas and Eastern New Mexico).

Broom snakeweed was effectively controlled for at least 3 years with 0.6 kg a.i./ha (80% wettable powder) tebuthiuron on the Southern High Plains. Total herbage production decreased following broom snakeweed control, but grass yield generally increased when the snakeweed was removed. Broom snakeweed control was not affected by application time during the year. However, grass production was significantly reduced for three growing seasons by application of tebuthiuron in May. Grass yield was not affected by applications in either November or January.

Herbel, C. H.   . Brush control in New Mexico. (mimeographed material). (Agronomist; research conducted in New Mexico).

SUMMARY AND CONCLUSIONS

The three basic methods of application are treatment of individual trees (or clumps in the case of multiple-stemmed or duned mesquite), use of ground application equipment, and aerial application. One of the most important factors to be considered in any method of application is effective control of basal buds (cotylendary buds), those buds located below ground (2 to 12 inches below the soil surface) on the transition area between the roots and shoot of the plant. If these buds are not killed, the trees will resprout from the base following top-killing.

1) Treatment of Individual Trees

Treatment of individual trees either chemically or mechanically, is most economical when the stand is sparse (50 to 150 trees/acre). Hand-grubbing is one of the oldest methods of mesquite control (Fisher 1947), yet it is not practical unless labor is cheap or it is used as a "clean-up" method following some other method of control.

Research into chemical treatment of individual trees began in the late 1930's using various chemicals, oils and creosote products (Fisher 1942). Sodium arsenite painted on cut stumps or poured into a frill effectively controlled mesquite (Fisher 1942; 1947).

Kerosene, diesel fuel or similar oils also effectively controlled mesquite when poured on the base of the stem and on the ground surrounding the tree (Fisher 1947). Oils are most effective when the soil is dry. One quart per tree (on sandy soils) to 1.5 qt/tree (on clay soils) is necessary to adequately penetrate the soil and envelop the basal bud zone (Fisher 1947; Tschirley 1963; Reynolds and Greer 1967). The ester formulation of

2,4,5-T has been added to diesel fuel when applied to bases of individual plants. It significantly increases the cost of control (Reynolds and Tschirley 1963), and it often does not significantly increase the effectiveness of control (Ueckert 1975). On the contrary, addition of 2,4,5-T ester (8 lb a.e./100 gal solution) to either diesel fuel or kerosene increased top-kill in mesquite in Oklahoma (Greer 1967) and Texas (Fisher et al. 1959). Weddle and Wright (1970) reported that diesel oiling either the basal stem of an intact tree or the stump of a cut tree effectively (50 to 85% root-kill) controlled mesquite regrowth with stem diameters ranging from 1 to more than 5 inches. Oiling becomes too costly to apply if there are more than 100 trees/acre (Reynolds and Tschirley 1963). Used crank case oil may be used to reduce the cost of application (Fisher et al. 1959).

Basal application of monuron (80% a.i. wettable powder) suspended in water or applied as a powder, and fenuron (25% a.i. pellets) have been used to effectively control mesquite, especially in the Southwest (Herbel no date; Fisher et al. 1959; Greer 1967; and Herbel 1970). High percent root-kills have been obtained with 1 level teaspoon of fenuron (1 g a.i.) /1.0 to 1.5 ft canopy diameter of small mesquite and 1 level tablespoon/yd^2 canopy diameter of larger mesquite growing in southern New Mexico (Herbel no date; Herbel 1970) and 1 tablespoon/4 inches stem diameter in Oklahoma (Greer 1967). Monuron is effective when applied as a powder (not suspended in water) at rates of 1 g a.i./ft canopy diameter (0.5 teaspoon equals 1 g a.i.) for mesquite plants up to 8 ft in diameter growing on sandy soil in southern New Mexico (Herbel 1970) and at rates of 0.5 teaspoon/plant with a canopy diameter of 1 ft or less, increasing the dose by 0.5 teaspoon/plant with a canopy diameter of 1 ft or less (Greer 1967). Rates must be increased on heavier soils. Both fenuron and monuron (especially applied as a dry powder) should be applied prior to the anticipated time of peak rainfall (Herbel, no date). Fenuron is conveniently applied from horseback (Herbel, no date) or any similar method, while monuron (applied as a powder) must be buried under surface soil to prevent photodecomposition (New Mexico Inter-Agency Committee, 1970).

Although Tandex® is not presently available, it effectively controls mesquite when applied to individual plants at rates ranging from 5 to 50 g a.i./tree with main stem diameter 4 inches or less (R. E. Sosebee unpublished data). It is also effective when applied broadcast (G. O. Hoffman, Extension Range Brush and Weed Control Specialist, Texas A&M Univ., personal communication).

Individual trees are sometimes sprayed using boomless nozzle equipment, in which case the trees are thoroughly wet with the herbicide solution (until the herbicide solution drips from the foliage). A low volatile ester formulation of 2,4,5-T or Silvex is recommended for spraying low-growing mesquite in Texas at a rate of 1 lb a.e./50 gal of water (Fisher et al. 1959). Recommendations for spraying individual mesquite trees in Oklahoma include 2 lb a.e. 2,4,5-T/100 gal of water (Greer 1967). In New Mexico, 1.25 lb a.e. 2,4,5-T/100 gal of water is recommended (Herbel, no date).

One of the newer methods of herbicide application to individual trees is the shredder-sprayer prototype being studied at Texas Tech University (Ulich and Turley 1976). (The shredder is similar to a standard Bush Hog shredder and the spray unit is designed to spray only the cut stumps and not the entire land surface traversed. The spray unit was originally designed and modified by Bob Koziol, Midland, Texas). This piece of equipment is designed to be mounted onto the front of a farm-type tractor (a large model-125 hp or more, or a front end loader). Individual stumps and the area immediately surrounding the stump are sprayed simultaneously with the shredding operation. Trees with basal stem diameters ranging from 3 to 8 inches can be shredded and sprayed with this equipment. Tordon 225 Mixture® is very effective (50 to 90% root-kill) when applied in aqueous solution (2 oz a.e./gal of water) just about any time during the year (Beck et al. 1975; Boyd et al. 1978). Boyd et al. (1978) found that dicamba and Banvel 2+2® gave intermediate response to Tordon 225 Mixture®. Results from shredding and spraying in May (time of greatest root carbohydrate depression) in the Rolling Plains of Texas are consistently higher than any other month of the year (Boyd et al. 1978). Shredding and spraying may, however, be done anytime of the year, including months when mesquite is dormant, if the upper 6 inches of soil is wet (Beck et al. 1975; Boyd et al. 1978). About 3 to 4 acres can be treated per hour with this method.

Most, if not all, individual plant treatments allow selective treatment of trees, which provides one the opportunity of manipulating the habitat, particularly for management of wildlife species. Treating individual plants usually requires more time to control large acreages of mesquite, but the control is usually more effective (higher percent root-kill) than any other treatments. Also, herbaceous plants outside the immediate area of control are damaged.

2) Use of Ground Application Equipment

Ground application equipment has been used to spray small trees, regrowth from basal buds following some other method of control, or seedlings. Boom-type sprayers (usually 20 ft in length) are the most common type of ground equipment used (although not very effective), however, a modified mistblower can also be used, with discretion. Large quantities of the spray solution generally are applied (20 to 125 gal/acre) at low pressures so the resultant spray occurs as large droplets (Fisher et al. 1959). If one elects to use a mistblower, certain precautions must be taken to prevent drift to non-target areas. Our research (Sosebee et al. 1976) indicates that if one uses the amine formulations of herbicides under the proper environmental conditions, mistblowers are safe.

Use of the mistblower can reduce the amount of herbicide solution to 1 or 2 gal/acre, thus reducing the cost of treatment. Swath widths obtained by using the mistblower are dependent upon equipment design and wind velocities, but the optimum is about 100 ft. The mistblower can either be mounted in the bed of a pick-up truck or on a trailor. Approximately 50 acres/hr can be sprayed with this equipment. This method can be quite effective in controlling low-growing mesquite or regrowth with lower rates of herbicides (0.125 to 0.250 lb a.e./acre) than generally can be achieved from aerial application. An area with low-growing mesquite was sprayed with 0.25 lb a.e./acre (total volume of 2 gal/acre) two consecutive years at a total cost of approximately $1.00/acre and resulted in an average 23% root-kill and essentially total top-kill of the mesquite (R. E. Sosebee and B. E. Dahl, unpublished data). Chemical companies neither sanction nor support the use of a mistblower because of the indiscriminate use made by ranchers in the past. It does, however, deserve further study.

Application of 1 lb a.e. 2,4,5-T/10 to 15 gal of water/acre is recommended for spraying small mesquite in Texas with a boom-type sprayer or lb a.e. 2,4,5-T/100 gal of water plus 2 to 16 oz of a suitable surfactant. For mesquite seedlings (in Texas) 6 months old or less, 2 lb a.e. 2,4,5-T/20 to 30 gal of water plus about 10 oz of a suitable surfactant is recommended (Hoffman 1973). In New Mexico, 0.5 lb a.e. 2,4,5-T, 5 pints of diesel and 16 gal water/acre are recommended for use with a 50-ft boom (Herbel, no date).

3) Aerial Application

Aerial application is the most common method of applying liquid herbicides, especially to large acreages, and new techniques are being developed to accurately apply pelleted herbicides (or granules) by airplane. Aerial application of herbicides has only been used since 1949 (Fisher et al. 1959). It is perhaps the most economical method used today to control large acreages of mesquite. Aerial application lends itself to treatment of extensive areas, regardless of density of the stand. Often treatment of mesquite following aerial spraying must be repeated every 5 to 7 years (Fisher et al. 1959). However, retreatment depends upon the amount of control received and may not be necessary for 10 to 12 years.

Often it is recommended that mesquite not be sprayed at a frequency greater than 5 year intervals because the mesquite is "too small" (Fisher et al. 1959). However, physiological age and condition of regrowth is probably more important than the chronological age (Beck et al. 1975). Spraying 1- and 2-year old sprouts of shredded mesquite (simulated aerial application) with the amine or ester formulation of 2,4,5-T and Tordon 225 Mixture® in combination with various synergists controlled 40 to 60% (percent root-kill after 2 growing seasons) of the plants (Sosebee 1972). Mesquite sprayed twice within a 4 year period in southern New Mexico essentially controlled all of the plants in the area (Herbel, no date).

Timing of liquid herbicide application is perhaps one of the most important factors influencing control of mesquite. It has long been recognized that the optimum time to spray mesquite is 50 to 80 or 90 days after bud burst (emergence of leaves) in the spring (Fisher et al. 1956; Fisher et al. 1959; Robison 1963; Haas et al. 1973; Hoffman 1975). Bud burst in mesquite is dependent upon the climatic conditions in the spring. Goen (1975) found that bud emergence in mesquite (in the High and Rolling Plains of Texas) is highly correlated (r=0.95) with minimum air temperature after the photoperiod reaches 11.5 hr (approximately March 1). Buds emerge 2 to 3 weeks after air temperatures are approximately 32 F (0 C) for 5 to 7 days after the photoperiod reaches 11.5 hr. Therefore, mesquite is most effectively controlled when sprayed from April 15 to July 15 in southern Arizona (Reynolds and Tschirley 1957), from April 30 to July 6 in central Texas (Meyer et al. 1972; Meyer 1977), and from May 20 to June 20 in southern New Mexico (Herbel, no date), and from late May to late June in northwest Texas (Scifres et al. 1973). It has been reported that 40 to 50 days after bud burst, maximum trunk growth (or radial expansion) occurs (Haas et al. 1973), leaves have matured (but still succulent) and turned from light to dark green (Reynolds and Tschirley 1962; Hoffman 1975), terminal growth (in twigs) is complete (Greer 1967; Herbel, 1970; Herbel no date; Tschirley 1962) and pods are about 0.5 inch long (Reynolds and Tschirley 1963) or elongated but not filled (Herbel, no date; Dahl et al. 1971a).

Adequate soil water content at the time of liquid herbicide application to mesquite has also been considered important (Herbel, no date; Fisher et al. 1959; Robison 1963; Greer 1967; Hoffman 1975). Control of mesquite growing on sandy soils or upland sites has generally been greater than in trees growing on clay soils or bottomland sites (Fisher et al. 1956; Fisher et al. 1959; Robison 1963). The two previous statements are contradictory because sandy soils are usually the driest and clay soils are usually the wettest. Dahl et al. (1971); and Dahl and Goen (1971) demonstrated that when 29 variables were considered, soil temperature at a depth of 12 to 24 inches (with an average at the 18-inch depth) was the most important factor affecting mesquite control with 2,4,5-T regardless of other range site characteristics (Table 4). If soil temperature was less than 74 F (23.5 C), herbicidal control of mesquite was essentially nil. When soil temperature increased above 80 F (26.7 C), mesquite control also increased. Dahl's study also revealed a negative correlation with the soil water content at all depths in the profile. These relationships have been supported by Sosebee et al. (1973) in mesquite control with Tordon 225.

Results from mesquite sprayed in numerous locations in the Rolling Plains of Texas and eastern New Mexico, on various range sites, and during several years (commercial jobs; no trees sprayed more than once), substantiated Dahl's earlier reports (B. E. Dahl and R. E. Sosebee, unpublished research). It appears that when soil temperature at a depth of 18 inches reaches 85 F (29.5 C) or 86 F (30 C), herbicidal control of mesquite is no longer effective. Meyer et al. (1972) reported that maximum soil temperatures of 63 to 79 F at a depth of 3 ft 1 week before treatment, lower maximum air temperatures of 77 to 96 F 1 week before treatment and decreasing soil moisture from 25 to 18% at a depth of 2 to 3 ft 1 week before treatment were the environmental variables most closely associated with mesquite control in central Texas. Apparently soil temperature is quite important in effective herbicidal control of mesquite during the early part of the spraying season (late spring-early

Table 4. Correlation coefficients[a] (r) relating plant root kill to various environmental measurements for the June and July herbicide treatments.

Environmental measurements	June	July
Soil Temperature 18 inch depth	.715 (1)[b]	.483 (3)[b]
Phenological development (stage of growth)	.613 (2)	.495 (2)
Soil Temperature 36 inch depth	.550 (3)	.430 (6)
Time of Day	-.426 (4)	-.195 (21)
Soil Texture (wilting coefficient)	-.392 (5)	-.561 (1)
Soil Temperature 24 inch depth	.349 (6)	.467 (4)
Water as % of the 30" storage capacity	.234 (7)	.113 (26)
Depth to effervescence with 10% HCl ($CaCO_3$)	-.314 (8)	-.451 (5)
Soil Temperature 12 inch depth	.291 (9)	.348 (8)
Relative Humidity	.241 (10)	.178 (23)
Available Water 0-6 inch depth	-.239 (11)	.206 (18)
Water as % of the 60 storage capacity	.190 (12)	.086 (27)
Available water 19-24 inch depth	.141 (13)	.135 (25)
Air Temperature	-.107 (14)	-.032 (28)
Soil Temperature 6 inch depth	-.090 (15)	.296 (11)
Accumulated available water 12 in dep	-.087 (16)	.343 (9)
Depth to $CaCO_3$ layer	.078 (17)	.219 (17)
Available water 31-36 inch depth	-.073 (18)	.189 (22)
Available water 7-12 inch depth	.065 (19)	.352 (7)
Available water 43-48 inch depth	.065 (19)	.196 (20)
Accumulated available water 18 inch dep	-.053 (20)	.311 (10)
Available water 25-30 inch depth	.035 (21)	.196 (20)
Accumulated available water 30 inch dep	.022 (22)	.253 (13)
Available water 13-18 inch depth	.018 (23)	.136 (24)
Accumulated available water 48 inch dep	.017 (24)	.229 (16)
Accumulated available water 24 inch dep	.014 (25)	.256 (12)
Accumulated available water 36 inch dep	.006 (26)	.243 (14)
Accumulated available water 42 inch dep	.005 (27)	.235 (15)
Available water 37-42 inch depth	.000 (28)	.204 (19)

[a] Coefficients (r) have to be .532 or greater to be significant at the 5% level.

[b] Rank or order of importance.

summer) but it is not as important during the latter part of the spraying season (Meyer 1977).

Perhaps phenological development (or stage of growth) or the physiological stage in which the plant is at the time of herbicide application is as important as soil temperature, especially during the latter parts of the spraying season (Dahl et al. 1971; Dahl and Goen 1971). Fisher et al. (1956) began examining the carbohydrate relationships of mesquite in the early 1950's. Since herbicides are translocated to the roots of mesquite via the carbohydrate stream, the carbohydrate trend in root carbohydrates can provide information when mesquite is the most susceptible to herbicide activity (Fig. 1). Tschirley and Hull (1959) reported a negative correlation between total sugar concentration and mesquite control with 2,4,5-T amine.

The root carbohydrate trend in mesquite characteristically contains three major depressions during the growing season (Wilson et al. 1975; Dyer and Dahl 1975; Fick 1978). The periods of root carbohydrate "recharge" in mesquite growing in the High and Rolling Plains occurs from late May to mid-June (about 3 weeks), late June to mid-July (10 days to 2 weeks), and either late July or early August (about 3 to 7 days). Typically, mesquite is more effectively controlled during these periods since the photosynthate translocation is primarily to the roots. Although most mesquite acreage in Texas is sprayed by July 1, many aerial applicators have indicated that some of their best results have occurred when trees were sprayed during the first ten days of July. Abundance of reproductive organs (flowers) also influence the carbohydrate relationships of the trees (Fig. 1). The amount of time required to "recharge" root carbohydrates in trees with few flowers is less than in trees with many flowers or a

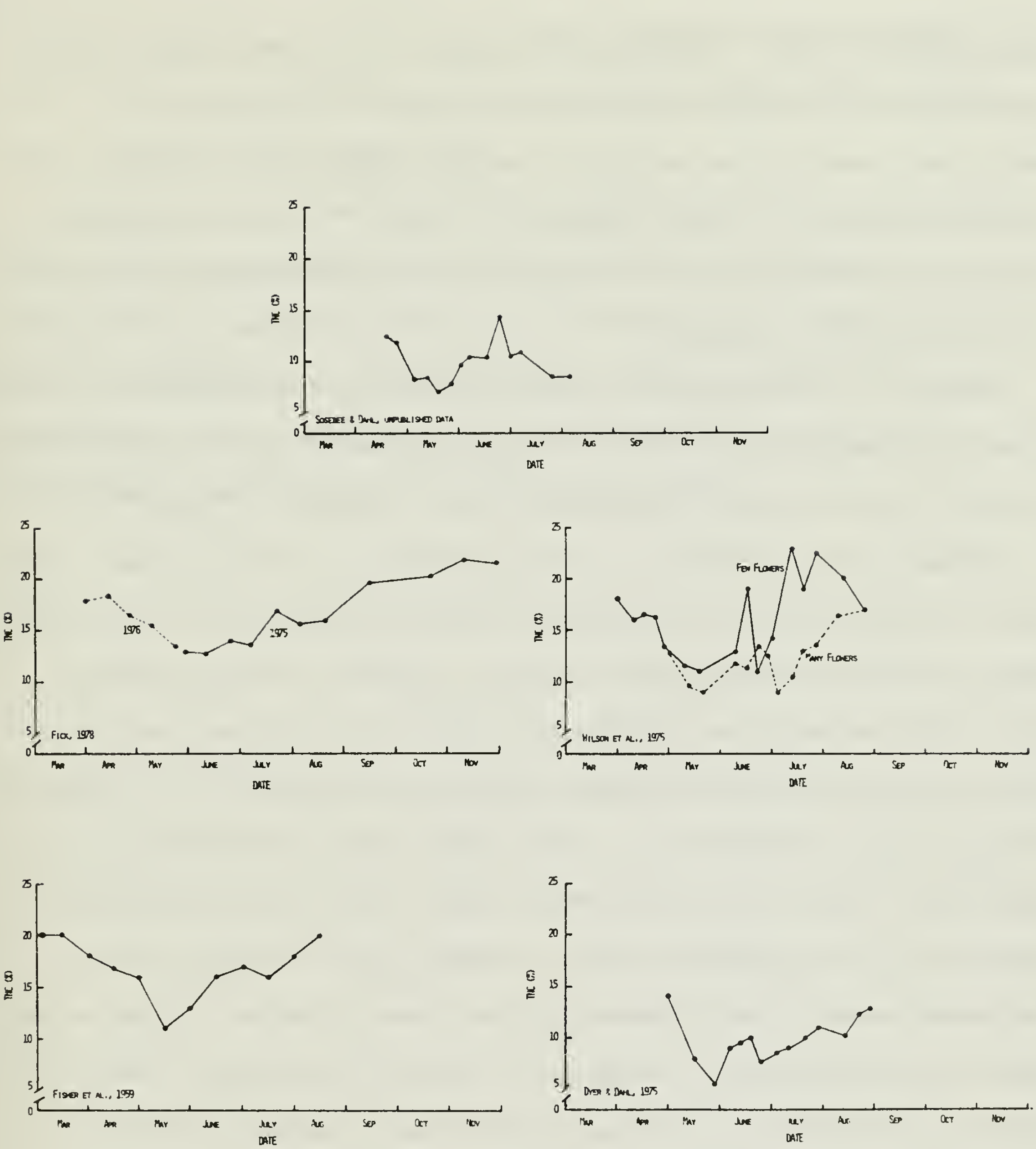


Figure 1. Total non-structural carbohydrates (TNC) of honey mesquite roots. Graphs were drawn from original presentations to conform to similar format. The data represent five different studies relating date and carbohydrate trends.

high reproductive load. Therefore, the amount of time that mesquite with few flowers can be sprayed and effectively controlled is reduced to about 1 to 2 weeks in June and only a few days during July. Although few (if any) applicators spray mesquite in August (it is not recommended), mesquite can effectively be controlled if it is sprayed during the period of root carbohydrate recharge.

Contrary to general opinion, relative humidity, air temperature at the time of herbicide application was poorly related to mesquite control (Dahl et al. 1971), as long as the soil temperature conditions were suitable for spraying.

Timing is not as critical for the application of dry herbicides. They should be applied prior to the expected peak in precipitation to facilitate dissolution and infiltration into the soil. However, our data (Sosebee et al. 1979) indicates that tebuthiuron applied in the spring, when grass growth begins, significantly reduces production for at least 3 or 4 years (perhaps longer). Either fall or winter application of tebuthiuron in the High Plains of Texas is more desirable because there is not a significant negative effect on herbaceous plants. Another factor to which we have just become aware is the influence of storm characteristics on erosion and run-on to non-target areas. Covectional storms in the spring, summer and early fall in the High and Rolling Plains of Texas commonly initially occur at rates of 3 to 10 inches/hr (D. J. Bedunah and R. E. Sosebee unpublished data). Even though these intensities may last only 5 to 15 min, run-off erosion is significant. If the dry herbicide was still on the surface of the soil at the time of one of these storms, much of it would likely be transported off the target area, onto a non-target area. Fall precipitation (in the High and Rolling Plains of Texas) characteristically occurs from frontal systems that are less intense and cause less runoff erosion. Therefore, it would be advisable to apply a dry herbicide in the fall when it could be dissolved and penetrate into to soil, rather than be washed off the target area.

An alternative to applying either a liquid herbicide to the foliage, base of the plant, or to a stump or dry herbicides to the soil is to combine the application technique with a rootplow (Hollingsworth 1973). This (or modifications) has been tested by the SEA personnel at College Station, but has not been pursued (to my knowledge) in recent years. Perhaps this area of research should be rejuvenated.

II. Effects on Related Resources

A. Watershed Values

1. Soil Erosion

SUMMARY AND CONCLUSIONS

The literature is largely devoid of information related to soil erosion resulting from spraying mesquite. Research conducted a few years ago on the Jornada Experimental Range in southern New Mexico indicates that chemical control of mesquite significantly reduced soil erosion caused by wind. Amount of soil blown was reduced from 955 to 61 tons/acre where mesquite was sprayed. Grass and forb production concomittantly increased with mesquite control (Walt Gould, personal communication).

We have just recently initiated research at Texas Tech in which one of the parameters being measured is runoff erosion resulting from mesquite control. At the time of this writing, our results are preliminary, but it appears that soil erosion following mesquite spraying is related to the amount of associated herbaceous vegetation present, and to the intensity of the storm.

Generally, associated herbaceous vegetation is not damaged by spraying mesquite, therefore, the soil surface remains protected (assuming a reasonable ground cover existed prior to spraying) and runoff erosion is not significant. However, the intensity of rainstorms in the southwest is quite high during late spring, summer, and early fall because of convectional storms. It is not uncommon for the rate to be 3 to 10 inches/hour for the first 5 to 15 min of the storm. Under these conditions, runoff erosion is likely to occur, regardless of the vegetative cover.

II. Effects on Related Resources
A. Watershed Values
2. Particulate matter (dust) in atmosphere

SUMMARY AND CONCLUSIONS

The literature is basically devoid of information relating to atmospheric particulate matter caused by spraying mesquite. The only related information was obtained on the Jornada Experimental Range where it has been shown that spraying mesquite reduces the amount of soil particules in the atmosphere.

Warren, G. F. 1954. Rate of leaching and breakdown of several herbicides in different soils. North Central Weed Control Conf. Proc. 11:5-6. (Credentials unknown, Purdue Univ.; location unknown).

The increasing use of herbicides that have a residual effect when applied to the soil has made it necessary to determine the movement and breakdown pattern of these chemicals in different soil types. The probable length of time the herbicide will be effective in killing weeds, the possible danger to succeeding crops, and the likelihood of preemergence applications moving to the crop seed represent some of the important information that can be gained from these studies.

In the experiments reported here an attempt was made to shorten and modify the methods reported by Ogle and Warren so that the relative breakdown and leaching behavior of herbicides could be determined rapidly. Studies were conducted on four soil types, namely, a fine sand, silt loam, "old" muck and "new" muck. The fine sand and silt loam contained 1.0 and 3.5% organic matter respectively while the muck soils were of organic origin. The "old" muck had been farmed for many years and was in a finely divided state while the "new" muck had been farmed only 1 year and was coarse and fibrous in nature. Activity of the herbicides following treatment was determined biologically by obtaining the fresh weight of crabgrass 14 to 18 days after planting 50 seeds.

For leaching studies, soil in cellophane columns was saturated 1 day, treated the next, leached with 2 inches of water on the third and sliced into 1 inch sections and planted with crabgrass on the fourth day. The activity was measured at the 0, 1, 2, and 4 inch depths as well as in the surface of treated but unleached soil. For breakdown studies the herbicides were mixed with the soil and kept moist by sub-irrigation in a warm greenhouse. Crabgrass was planted to measure activity at 0, 2, 4, and 8 weeks.

In the leaching experiments, CMU and 3-(3,4,-dichlorophenyl)-1,1-dimethyl urea (DCMU) were used at the rate of 2 lb/acre. The amine salt of MCP and the amine salts and propylene glycol butyl ether esters of 2,4-D, 2,4,5-T and 2(2,4,5-trichlorophenoxy) propionic acid (Silvex) were applied at 4 lb a.e./acre. CIPC, TCA (sodium salt), dichoral urea, sodium 2, 2-dichloropropionate (Dalapon) and the sodium ethyl sulfate forms of 2,4-D (SES) and 2,4,5-T (Natrin) were all applied at an 8 lb rate. DNBP (amine salt) and PCP (sodium salt) were used at 16 and 32 lb, respectively. In the breakdown studies the same quanities were used on the mineral soil but the rates were <u>doubled</u> on the mucks.

Warren 1954 (con't.)

The herbicides showed many decidely different patterns of leaching which varied with soil type. The pattern of movement appeared to be influenced both by the strength of absorption of the herbicide, by the soil and by relative solubility in water. Two chemicals, the sodium salts of TCA and Dalapon, were absorbed to a minor extent if at all since they leached readily and showed the same pattern in all four soils. All of the other weed killers were apparently absorbed to some extent since they moved less in the silt loam and muck soils than in the fine sand. In general, these herbicides showed greatest movement in the sandy soil and progressively less in the silt loams, "new" muck and "old" muck.

Pierco, M. E. 1958. The effect of the weedicide Kuron upon the flora and fauna of two experimental areas of Long Pond, Dutchess County, N.Y. Northeastern Weed Control Conf., Proc. 7:338-343. (Credentials unknown, Vassar College; research conducted near Poughkeepsie, N.Y.).

1. Long Pond is a very shallow body of water, rapidly filling in with pondweeds of the emergent, floating, and submergent types. The species *Mynphaea odorata* was of special concern in these experiments.

2. Two experimental plots (50 x 100 ft) and one control (100 x 100 ft) were selected along the shore. The control was located between the experimental plots.

3. Preliminary study of the following conditions in these three plots was made in early May 1957; temperature, pH, O_2 in ppm, plankton, benthic organisms, large aquatic vertebrates, and aquatic plants. This routine was repeated at intervals namely, June 9, June 30, July 17, and October 1, 1957.

4. The experimental plots were twice sprayed with Kuron, an herbaceous weed killer. The dates of the spraying were June 8 and June 29. The effective concentration proved to be roughly 1½ gal/acre.

5. The effect of the Kuron was to accelerate the growth of the stems of *Nymphaea* within a few days, after which they became weakened, broke off, and both stems and leaves died. After 4 weeks the surface of the water was fairly well cleared of lily pads; after 6 weeks better cleared, and after 9 weeks almost completely cleared.

6. After 6 weeks, new shoots began to appear from the rhizomes, but these were not as numerous as the original leaves. After 9 weeks some of these reached the surface.

7. The Kuron did not appear to weaken or kill any of the submerged weeds.

Pierco 1958 (con't.)

8. The temperature of the bottom water of the pond varied from 68° F in May to 78° F during July and returned to 60° F in October.

9. The pH was very constant, varying only from 7.3 to 7.5.

10. The dissolved oxygen content varied from 8 ppm in May to 5.5 ppm in June and July, returning to 7.5 ppm in October.

11. Plankton was constantly represented by the following groups: Myxophyceae, Chlorophyceae, Flagellata, Rotifera, Annelida, Crustacea. Usually several species were present within each group, but not necessarily the same species at all times.

12. Benthic forms were represented constantly and by greater numbers of individuals in the following groups: Gastropoda, Pelecypoda, Amphipoda, and Mayflies. They were represented irregularly and in smaller numbers of individuals by Annelida, Odonata, and Diptera.

13. Although precise quantitative studies were not carried out, it appears that both plankton and benthic organisms maintained their number of individuals and variety of species in a normal pattern for the pond.

14. The large aquatic vertebrates, fish, frogs and turtles, were constantly present. Many small schools of small (probably young) fish were regularly seen swimming in the experimental plots.

15. At present, on the basis of data obtained and studied, the only change resulting from the application of Kuron was the destruction of the water lily.

Whiteside, J. S. and M. Alexander. 1960. Measurement of microbiological effects of herbicides. Weeds 8:201-213. (Graduate Asst., and Assoc. Prof., Dep. of Agronomy, Cornell University; laboratory study conducted at Cornell).

A method is described for measurement of the effect of several herbicides on soil respiration using oxygen consumption in the decomposition of native soil organic matter or added carbonaceous materials as the criterion. No microbiological effect could be found at rates of application corresponding to those used for weed control.

Whiteside and Alexander 1960 (con't.)

By measurement of the changes in ultraviolet absorption of herbicide solutions inoculated with soil, it has been shown that 4-(2,4-dichlorophenoxy) butyric acid and 2,4-dichlorophenoxyacetic acid are metabolized by the soil microflora, and the possibility of the latter being formed in soil from the former is suggested. No evidence has been found for a microbiological attack of 2,4,5-T, 4-(2,4,5-TB), 2-(2,4,5-TP) and 2-(2,4-DP) sufficient to cause a disappearance of the ultraviolet absorption. The advantages of the spectrophotometric technique for measuring microbiological decomposition of aromatic herbicides are considered, and several specific applications are illustrated.

Winston, A. W. Jr., and P. M. Ritty. 1961. What happens to phenoxy herbicides when applied to a watershed area. Northeastern Weed Control Conf., Proc. 10:396-400. (The Dow Chemical Co., Midland, Mich.; laboratory study conducted at Midland, Mich.).

Studies of the degradation products of 2,4-D, 2,4,5-T and silvex have been made. The results of these studies show conclusively that decomposition under natural conditions does not result in the formation of the corresponding phenols. These phenoxy herbicides are decomposed into carbon dioxide, hydrochloric acid and water. Free phenols are decreased, rather than increased, by bacterial degradation and are not the breakdown products of phenoxy herbicides. Bacterial oxidation of phenoxy herbicides produces a quantitative release of chloride ions. Aromatic oils have a much lower taste and odor theshold than the active ingredients in reputable phenoxy herbicide formulations. These oils, however, are decomposed even more rapidly than the phenoxy component. Therefore, reputable commercial formulations properly applied to watershed areas do not constitute a water pollution hazard.

Faust, S. D., R. J. Tucker and O. Aly. 1961. A preliminary report on the effect of some aquatic herbicides on water quality. Northeastern Weed Control Conf., Proc. 10:546-548. (Asst. Prof., Research Tech., and Research Asst., Dep. Sanitation, Rutgers University; laboratory study conducted at Rutgers).

Burger, K., I. C. MacRae, and M. Alexander. 1962. Decomposition of phenoxy alkyl carboxylic acids. Soil Sci. Soc. Am., Proc. 26:243-246. (Chemical Analysist, Research Assoc. and Assoc. Prof., Dep. Agronomy, Cornell University; laboratory study conducted at Cornell).

The persistence of phenoxy alkyl carboxylic acids in soil was measured by a bioassay technique using alfalfa seedlings. Acetic, alpha-propionic and alpha- and gramma-butyric acid derivatives were toxic when applied to soil planted to alfalfa whereas the beta-propionic acid derivatives showed no inhibition of the test plant. All 3,4-dichloro- and 2,4,5-trichlorophenoxy alkyl carboxylic acids exhibited prolonged persistence in soil. The duration of phyto-toxicity in soil receiving 4-chloro-, 2,4-dichloro- and 2-methyl-4-chlorophenoxyalkyl carboxylic acids was governed by the type and linkage of the aliphatic side chain.

A *Flavobacterium* sp. active in the degradation of phenoxybutyric acids was isolated. The bacterium metabolized only phenoxy butyric acids having no meta chlorine on the aromatic ring. In the decomposition, the organic chlorine was liberated and the aromatic ring cleaved.

The results demonstrate that specific structural characteristics of these herbicide molecules govern persistence of the compounds in soil.

Thiegs, B. J. 1962. Mycobial decomposition of herbicides. Down to Earth (Fall):7-10. (Title unknown, Biomechanism Section, The Dow Chemical Co., Midland, Mich.; literature review).

Microorganisms play a major role in the detoxification of herbicides in the soil and factors affecting the activity of the organisms generally also affect herbicidal decomposition. Present evidence indicates that the decomposition of the chlorophenoxyacetic acid herbicides results in the formation of chloromuconic acids which are further metabolized with chlorine liberation. Some structural relationships which affect the persistence of the phenoxyalkyl carboxylic acid herbicides in soil are given.

The decomposition of the chloro-substituted aliphatic acids is usually accompanied by a dehalogenation.

The detoxification of many herbicides by soil microorganisms is an important part of their successful use since this prevents residues from accumulating. Under favorable conditions some herbicides such as 2,4-D and dalapon, are decomposed fairly rapidly by soil microorganisms.

Wiese A. F. and R. G. Davis. 1964. Herbicide movement in soil with various amounts of water. Weeds 12:101-105. (Agron., USDA-ARS, and Tech., Texas Agr. Exp. Sta., Bushland, Texas; research conducted at the Southwestern Great Plains Field Sta., Bushland).

When applied in enough water to wet tubes of dry Pullman silty clay loam top soil to a depth of 22 inches, dimethylamine salts of 2,3,6-trichlorobenzoic acid (2,3,6-TBA) and polychlorobenzoic acid (PBA) were leached to about 20 inches; an amine salt of 2,4-dichlorophenoxy-acetic acid (2,4-D) and the sodium salt of 2,3,5-trichlorophenylacetic acid (fenac) leached to 15 inches; esters of fenac, 3-phenyl-1, 1-dimethylurea (fenuron), 3-(p-chlorophenyl)-1, 1-dimethylurea (monuron) and amine salts of 2-(2,4,5-trichlorophenoxyl) propionic acid (Silvex) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) leached to approximately 9 inches. Esters of silvex, 2,4,5-T, and 2,4-D remained in the top 3 inches of soil. The leaching with additional water was in the same general order as just given.

Alexander, M. 1965a. Biodegradation: problems of molecular recalcihance and microbial fallibility. Advan. Appl. Microbiol. 7:35-80. (Assoc. Prof., Dep. Agron., Cornell University; research conducted at Cornell).

In the preceding discussion, a variety of environmental and chemical factors affecting the biodegradability or rate of decomposition of organic compounds and natural materials was considered. Compiling data, though time-consuming, is not too difficult; providing explanations for these observations is, at the present time, almost impossible. However, some comments and suggestions can be advanced, but these clearly must be, in the absence of sufficient experimentation, frequently naive or, at best, inadequate.

Among the factors which probably affect the biodegradability or decomposition rate of organic materials, the following can be cited:

1. *Inaccessibility of the substrate.* The compound may be deposited in a microenvironment which precludes microbial approach, it may be absorbed to clay or other colloidal matter, or it may become entrapped or embedded within a nonmetabolizable or slowly degraded substance that prevents the organism or its enzymes from reaching the substrate.

2. *Absence of some factor essential for growth.* For example, no activity would occur should water, nitrogen, or a biologically utilizable terminal electron acceptor be unavailable.

Alexander 1965a (con't.)

3. *Toxicity of the environment.* This could result from biologically generated organic inhibitors, microbially formed inorganic toxins, high salt concentrations, extremes of temperature, acidity, or some other environmental condition outside of the range suitable for microbial proliferation.

4. *Inactivation of the requisite enzymes.* Enzymes may lose activity by absorption to clay minerals or other colloids, or they may be inhibited by their phenolic and polyaromatic substrates or products.

5. *A structural characteristic of the molecule which prevents the enzyme from acting.* For example, terminal quaternary groups, non-alkyl substituents, or extensive branching on the aliphatic moiety might markedly affect the microbial decomposition of alkyl benzene derivatives, particularly where the degradation must be initiated by α- or β-oxidation of the alkyl portion of the molecule. Similarly, substituents that do not permit enzyme approach to the site upon which it acts could delay or prevent decomposition. The evidence summarized above suggests that the introduction of halogens, nitro, methyl, or other substituents imparts resistance to certain compounds.

6. *Inability of the community of microorganisms to metabolize the compound because of some physiological inadequacy.* An enzyme capable of coping with the compound may simply not exist. Alternatively, the substrate may not be able to penetrate into cells which have the appropriate enzymic composition.

Alexander 1965b. Persistence and biological reactions of pesticides in soils. Soil Sci. Soc. Amer., Proc. 29:1-7. (Assoc. Prof., Dep. Agron. Cornell University; research conducted at Cornell).

Although microorganisms are often considered to be omnivorous and biochemically omnipotent, they seem unable to destroy our significant rates many synthetic chemicals that enter soil. This unexplained microbial fallibility recently has assumed prominance because of the long persistence of a variety of pesticides. With at least certain compounds, the chemical, physiological or environmental basis of the biological failings can be established, as illustrated with substituted phenols and phenoxy herbicides.

Microorganisms may detoxify pesticide-treated soil by metabolizing or degrading the added substance. The microflora may also be responsible for the generation of a toxic condition in soil by activation of the applied pest-control agent. The use of laboratory precedents as guides in investigations of natural transformations is considered, and instances of pesticide metabolism in soil are cited.

Newman, A. S. and C. R. Downing. 1965. Herbicides and the soil. J. Agr. Food Chem. 13:72-76. (Titles unknown, USDA-ARS, Washington, D.C., and Virginia-Carolina Chemical Corp., Virginia; compilation of several research studies).

The least persistent herbicides in a silt loam soil were dalapon, 2,4-D amine, 2,4-D ester, sodium 2-(2,4-dichlorophenoxy) ethyl sulfate, and isopropyl N-(3-chlorophenyl) carbamate. The most persistent compounds included 4,6-dinitro-o-sec-butylphenol, monuron, and diuron. Persistence was somewhat less for some compounds in muck, and somewhat greater for some in a fine sand. TCA and dalapon leached readily in all soils, while diuron and CIPC were high resistant to leaching. Other showed intermediate leachability.

The adsorption of herbicides was determined by ascertaining the amount of compound required to cause 90% inhibition of crabgrass growth in silica sand, a fine sandy soil, a silt loam, a new muck, and an old muck. There was little adsorption of TCA, dalapon, or 2,3,6-trichlorobenzoic acid by any of the soils. In contrast monuron, diuron, DNBP, CIPC, and pentachlorophenol were strongly adsorbed. It required 24 to 90 times as much of these to cause 90% inhibition in old muck as in silica sand.

With the presently employed herbicides there is no indication that normal applications will seriously injure soil microorganisms or microbial processes. In general, extremely high rates are required to cause significant effects on the soil population. Higher plants are much more sensitive to herbicides than are the soil microflora. In some instances normal rates of treatment may be injurious to organisms in a thin layer of soil, but rapid recovery of these organisms can be expected upon disappearance of the herbicide.

The principal cause of the disappearance of many herbicides from soils is microbial decomposition. Removal by leaching, adsorption by soil colloids, and volatilization are other important causes.

Brown, E. and Y. A. Nishioka. 1967. Pesticides in water. Pesticides in selected western states--a contribution to the national program. Pestic. Monitor. J. 1(2):37-46. (Titles unknown, Water Resources, U.S.D.I.-G.S., Sacramento, Calif.; research conducted from samples collected from 11 streams in western U.S.).

Brown and Nishioka 1967 (con't.)
Since October 1965, samples of a water-suspended sediment mixture from 11 streams in the western United States have been analyzed monthly for 12 pesticides. The compounds determined include the insecticides aldrin, DDD, DDE, DDT, dieldrin, endrin, heptachlor, heptachlor epoxide, and lindane; and the herbicides 2,4-D; 2,4,5-T; and silvex. No herbicide was found at any station during the first year of the sampling program. All insecticides were found at one time or another, but not at all station. The amounts observed were quite small, ranging from less than 5 parts per trillion of lindane to 110 parts per trillion of DDT.

Green, R. S. and S. K. Love. 1967. Pesticides in water. Pestic. Monitor. J. 1(1):13-16. (Titles unknown, Division of Pollution Surveillance, Fed. Water Pollution Control Adm., USDA and Quality of Water Branch, USDA-GS, Washington, D.C.; surveillance of pesticides in surface waters throughout U.S.).

The purpose of this program is to provide continuing information on the overall extent of pesticide contamination of the Nation's water resources. The objective has been to develop the minimum program that will enable an adequate assessment of conditions. Within this objective, monitoring currently is confined to the examination of surface waters in the major drainage rivers of the United States through a nationwide network of sampling locations. Over a period of years, it is expected that data obtained from this network will reflect important changes in pesticide levels in these rivers.

Davis, E. A., P. A. Ingebo, and C. P. Pase. 1968. Effect of watershed treatment with picloram on water quality. U.S. Dep. Agr., Forest Service Res. Note RM-100. 4p. (Plant Physiologist, Hydraulic Eng., and Plant Ecologist, Tempe, Arizona, Arizona State University; location where research conducted unknown).

A watershed treatment of soil-applied picloram pellets for the control of chaparral brush resulted in the movement of detectable amounts of picloram into the stream water. The highest concentration found was 0.37 ppm. After 16 months and 40 inches of accumulated rainfall, picloram was no longer detectable in the stream water.

Trichell, D. W., H. L. Morton, and M. G. Merkle. 1968. Loss of herbicides in runoff water. Weed Sci. 16:447-449. (Grad. Asst. and Plant Physiologist, USDA-ARS, and Assoc. Prof., Dep. Soil and Crop Sci., Texas A&M University; research conducted near College Station, Texas).

The loss of 2-methoxy-3,6-dichlorobenzoic acid (dicamba), 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), and 4-amino-3,5,6-trichloropicolinic acid (picloram) in runoff water was determined with a gas chromatograph and bioassays. When determined 24 hr after application, losses of dicamba and picloram were greater from sod plots than from fallow plots while 2,4,5-T losses were about equal. Four months after application, losses of all herbicides averaged less than 1% of that lost 24 hr after application. The amount of picloram lost in a simulated rainfall of 0.5 inch varied with rate, but the percentage lost was the same. The slope of the plot and movement over untreated soil influenced the percentage of picloram lost. The maximum loss obtained for any herbicide was 5.5% and the average approximately 3%.

Wershaw, R. L., P. J. Burcar, and M. C. Goldberg. 1969. Interaction of pesticides with natural organic material. Environ. Sci. Tech. 3(3): 271-273. (Titles unknown, U.S.G.S., Denver; laboratory research conducted in Denver).

Two examples of the interaction of pesticides with natural organic materials have been investigated. Sodium humate solubilizes DDT in water and humic acid strongly sorbs 2,4,5-T. These two types of interactions are indicative of the types that one would expect when any organic pesticide is applied to a natural soil-water system.

Haas, R. H., G. O. Hoffman, and M. G. Merkle. 1970. Persistence of picloram in natural water sources. Texas Agr. Exp. Sta. PR 2825, p. 86-90. (Asst. Prof., Brush and Weed Control Spec., Assoc. Prof. Texas A&M Univ., College Station; location where research conducted unknown).

Haas et al. 1970 (con't.)

Analyses for picloram in water samples collected at several locations in Texas show that picloram was found in nonflowing surface water collected adjacent to treated areas. The picloram concentration diminished as a decay function with time and rainfall amount. In most cases picloram concentrations were found to have approached the detection limits within 6 months after application. Where 1 lb of picloram was applied directly to a stock water pond at College Station, significant amounts of picloram were retained at 11 months following application.

Picloram was not detected in flowing water below treated areas after rains sufficient to produce runoff. No contamination of well water has been detected 2 years following treatment of adjacent surface areas.

Hahn, R. R., C. J. Scifres, and M. G. Merkle. 1970. Rate of picloram disappearance from earthern stockponds. Texas Agr. Exp. Sta. PR 2824, p. 84-86. In, Brush Research in Texas. Consolidated Prog. Rep. 2801-2828. Texas A&M University. College Station. (Res. Assoc., Asst. Prof., and Assoc. Prof., Texas A&M Univ., College Station; location where research conducted unknown).

Data presented indicate that the greatest loss of picloram from natural bodies of water occurs in about 3 to 4 weeks. After that time, the rate of breakdown is fairly constant and centers around a loss of 0.02 to 0.03 parts per billion per day.

Mullison, W. R. 1970. Effects of herbicides on water and its inhabitants. Weed Sci. 18:738-750. (Title unknown, Agr. Dep., Dow Chemical Co., Midland, Mich.; literature review).

There is little evidence that herbicides from agronomic or industrial usage are reaching or accumulating in our water supplies in amounts to cause a pollution problem. Fish tolerance to weed killers varies with their size and species as well as with differences in the aquatic site. There may be variation to different forms of the active ingredient. Other components in a formulation may be more toxic than the herbicide itself. Therefore, the LD_{50} of different formulations should be determined. In addition, the manner and other circumstances involving application of a herbicide may change its toxicity to water

Mullison 1970 (con't.)

inhabitants. Our current knowledge of the effects of herbicides on fish, plankton, and other water inhabitants indicate that harmful effects with our present herbicides, when such exist, are only temporary. Available evidence suggests there is no biological magnification problem with herbicides.

Stevens, L. J., C. W. Collier, and D. W. Woodham. 1970. Pesticides in soil. Monitoring pesticides in soils from areas of regular, limited, and no pesticide use. Pestic. Monitor. J. 4(3):145-164. (Titles unknown, USDA-Plant Protection Div., Hyattsville, Md. and Gulfport, Miss.; samples monitored throughout U.S.).

Pilot studies were conducted nationwide at 51 locations in 1965, 1966, and 1967 to determine existing pesticide residue levels in soils. Samples were collected from 17 areas in which pesticides are used regularly, 16 areas with a record of at least one pesticide application and in 18 areas with no history of pesticide use. The samples were analyzed by gas chromatography.

A wide variety of pesticides were found in soils from areas of regular use. Residues of DDT and dieldrin were found in soils where pesticide use has been limited. Except for a small amount of DDT found in soil from one No Use Area, all other samples from the No Use Areas were negative.

Bachelard, E. P. and M. E. Johnson. 1971. A study of the persistence of herbicides in soil. Weed Abstr. 20:58 (Aust. For. 33:19-24, 1969). (Credentials unknown; location where research conducted also unknown).

The presence of Tordon 50D (picloram tri-isopropanolamine-2,4-D in the proportions 1:4) and 2,4,5-T in soil reduced the emergence of survival of *Pinus radiata* seedlings, the major effect being on survival. Effects of 2,4,5-T disappeared rapidly (within 2 months of application), whereas some effects of Tordon 50D persisted for at least 6 months. Sterilization of the soil by autoclaving did not delay breakdown of the herbicide, nor did leaching of the soil hasten the decline of its activity. The herbicides affected initial growth of seedlings, but older seedlings would suffer little or no damage if planted on sites treated with these herbicides a few months previously.

Edwards, W. M. and B. L. Glass. 1971. Methoxychlor and 2,4,5-T in lysimeter percolation and runoff water. Environ. Contam. Toxicol., Bull. 6:81-84. (Titles unknown, North Appalachian Exp. Watershed, Coshocton, Ohio, and USDA Soils Laboratory, Beltsville, Md.; research conducted at the North Appalachian Exp. Watershed).

This report describes the transport of a chlorinated hydrocarbon insecticide, methoxychlor, and a water-soluble herbicide, 2,4,5-T, in runoff and percolation from a field lysimeter. Runoff and percolation resulting from natural rainfall were monitored for 14 months following the March 30, 1967 surface application of 11.2 and 22.4 kg/ha of 2,4,5-T and methoxychlor, respectively.

Runoff is this period carried over 5.5 g/ha or 0.05% of the applied 2,4,5-T. As evident in Table 1 and Figure 1, the bulk of the 2,4,5-T removal in the runoff took place within the first 4 months after application, and more than half of the loss took place within 32 days. Over 25% of the entire loss was associated with one storm event occurring 21 days after application, when the concentration in the runoff reached a maximum of 300 μg/liter. It is noteworthy that the amount of runoff water during this event was relatively small.

The total amount of 2,4,5-T found in the percolate was so small that it did not indicate significant contribution to groundwater contamination. The rapid degradation rate explains why this soluble herbicide did not persist long enough in the soil water system to move freely to the sampling depth. Only by rapid flow through large channels and deep soil cracks can 2,4,5-T move out of agricultural soils into deep ground water supplies.

Scifres, C. J., R. R. Hahan, J. Diaz-Colon, and M. G. Merkle. 1971. Picloram persistence in semiarid rangeland soils and water. Weed Sci. 19: 381-384. (Asst. Prof., Research Assoc., Agr. Research Tech., USDA-ARS, and Prof., Dep. Soil and Crop Sci., Texas A&M University; research conducted at 7 locations throughout the Rolling Plains of Texas).

Residues in soil, following application of 0.25 lb/acre of 4-amino-3,5,6-trichloropicolinic acid (picloram) to semi-arid rangelands, usually were restricted to the top 12 inches at 120 to 180 days after application; but picloram usually dissipated from the soil profile within a year. More picloram was detected 5 months after application at 6 to 18 inches deep at the lower ends of plots with 3% slopes than

Scifres et al. 1971 (con't.)
plots with 0, 1, or 2% slopes. Runoff water from plots irrigated 10 days after treatment contained 17 ppb picloram. Irrigation or rainfall at 20, 30, or 45 days after picloram application resulted in less than 1 ppb picloram in runoff water. No more than 1 or 2 ppb picloram were detected after dilution of runoff water in large ponds.

Altom, J. D. and J. F. Stritzke. 1973. Degradation of dicamba, picloram, and four phenoxy herbicides in soils. Weed Sci. 21:556-560. (Research Asst. and Asst. Prof., Dep. Agron., Okla. State Univ.; research conducted near Stillwater, Okla.).

The degradation rates of 2,4-D, 2,4,5-T, silvex, dicamba, and picloram were determined in three soils. Herbicide breakdown was proportional to herbicide concentration, so half life of the various herbicides was calculated from linear regression of the logarithm transformed residue data. The average half life for 2,4-D, dichlorprop, silvex, 2,4,5-T, dicamba, and picloram were respectively, 4 days, 10 days, 17 days, 20 days, and greater than 100 days. The rate of degradation of 2,4-D was the same in all three soils, but for the other herbicides it was consistently faster in soil removed from under grass vegetation than from under trees.

Davis, G. G. 1973. Fluometuron and 2,4,5-T residues in soil, sediment, runoff water, and percolation water. Ph.D. Dissertation. Univ. Tennessee. Knoxville. (Diss. Abstr. 34:5285B-5236B). (Grad. Student; research conducted in Tennessee).

The rates of disappearance of 1,1-dimethyl-3-(a,a,-trifluoro-m-tolyl) urea (fluometuron) and the propylene glycol butyl ether esters and a triethylamine salt of (2,4,5-trichlorophenoxy) acetic acid (2,4,5-T) from the application site in field plots and lysimeters were determined. Residual herbicide concentrations were estimated for field plot soil, runoff water collected in the plots after rainfall, and permanently impounded drainage water from the plots. Bioassays, spectrophotometry, and gas-liquid chromatography were utilized to detect residual concentrations of the three compounds. Linear and multicurvilinear equations were developed from known concentrations of the herbicide for prediction of residue amounts in the field plots and lysimeters. The effects of the herbicides on forage sorghum plant density and the relationship of stand to forage yield were evaluated.

Davis 1973 (con't.)

Preemergence application of fluometuron and 2,4,5-T reduced forage sorghum plant density to 75 and 43% of the control, respectively. The annual mean yield of oven-dry forage was 824 g/m^2. There were no differences between forage yields from treated and untreated plots or between weed-free and weedy control plots when means were tested at the 0.05 level of probability.

The herbicides applied to the surface of Etowah silt loam were detected in the 0 to 1 cm depth of the plot soil within 7 days of application. After 60 days no residue could be detected in the 0 to 1 cm zone. Fluometuron and 2,4,5-T herbicides present in the 0 to 15 cm soil zone and fluometuron in the 30 to 45 cm soil zone 14 days following application were degraded or leached from the sampling area in 7 months. Fluometuron was present on day 210 following initial herbicide application but only in plots which are resprayed during the season.

The mean concentration of 2,4,5-T detected in impounded water was 0.04 ppmw. Detectable amounts of 2,4,5-T were not present in fresh runoff water collected in the plots. The ester formulation of 2,4,5-T dissipated more slowly in the impounded water than it did in field plot soil. No 2,4,5-T residues were detected in water 7 months following herbicide application.

No detectable quantities of fluometuron residues were found in runoff and impounded water from the field plots 60 days following initial herbicide application. Fluometuron was degraded as rapidly in water as it was in soil.

Residual fluometuron and 2,4,5-T of both formulations were present in lysimeter percolation water 1 to 16 days following application to the soil surface. No detectable residues were present in lysimeter percolation water 90 days following herbicide application.

The data collected in this study indicate that the herbicide treatments did not permanently modify the application site or the nontarget sites to which the compounds migrated. No residual compound from the initial herbicide application could be detected at the end of the crop season.

Khan, S. U. 1973. Equilibrium and kinetic studies of the adsorption of 2,4-D and picloram on humic acid. Can. J. Soil Sci. 53:429-434. (Titles unknown, Research Station, Agriculture Canada, Regina, Sasketchewan; laboratory study conducted in Regina).

Khan 1973 (con't.)

Equilibrium and kinetic studies of the adsorption of 2,4-D and picloram on a humic acid have been made. The equilibrium data followed the Freundlich-type isotherm. Rate constants, activation energies, heats of activation, and entropies of activation were calculated for the adsorption of the two herbicides on humic acid. The rate data indicated a physical type of adsorption. In the overall adsorption process the rate-limiting step for the initial period was shown to be the diffusion of the herbicide molecules to the surface of humic acid. However, the rate-limiting process at longer time intervals was interpreted to be intraparticle diffusion of the herbicide molecules into the interior of the humic acid particles.

Schulze, J. A., D. B. Manigold, F. L. Andrews. 1973. Pesticides in water. Pesticides in selected western streams--1968-71. Pestic. Monitor. J. 7:73-84. (Titles unknown, USDI-GS, Water Resources Div., Austin, Texas; research conducted on samples collected throughout western U.S.).

Compounds determined include the common chlorinated insecticides and herbicides. Heptachlor and its epoxide were not detected during the 3-year period, and aldrin was found only once. DDT was the most frequently occurring insecticide, and 2,4,5-T the most common herbicide. The amounts observed were small; the maximum concentration of an insecticide was 0.46 μg/liter for DDT, and of an herbicide 0.99 μg/ liter for 2,4-D. Concentrations were highest in water samples containing appreciable amounts of suspended sediments. Graphs are included to show insecticide and herbicide occurrences for the 4-year period (October 1967-September 1971) during which all 20 monitoring stations have been in operation.

Beginning in July 1970, the phosphorothioate insecticides--parathion, methyl parathion, malathion, and ciazinon--were determined monthly on all samples. Malathion was not found during this period. Polychlorinated biphenyl (PCB's) compounds which were monitored for beginning in October 1969 were also detected at two stations.

Scifres, D. J. and T. J. Allen. 1973. Dissipation of dicamba from grassland soils of Texas. Weed Sci. 21:393-396. (Assoc. Prof. and Asst. Prof., Dep. Range Science, Texas A&M University; research conducted near Wheelock in Robertson Co., Texas).

Dicamba dissipated in 4 weeks and in 9 to 16 weeks when sprayed on grassland soils of Texas at 0.28 kg/ha and 0.56 kg/ha, respectively. At three or four locations ranging from humid to semiarid and from clay to sandy loam and sampled from 9 to 63 weeks after treatment, usually residues were no deeper than 120 cm and never deeper than 150 cm. However, dicamba residues were detected 120 cm deep 53 weeks after application of granules at 1.68 or 2.24 kg/ha to sand of semiarid grassland. Since dicamba sprays are usually applied at 0.56 kg/ha or less for grassland restoration in Texas, it is unlikely that residues of dicamba will persist in soil through the growing season from spring application.

Weber, J. B., T. J. Monaco, and A. D. Worsham. 1973. What happens to herbicides in the environment. Down to Earth 29(3):12-14. (Titles unknown, North Carolina State University, Raleigh, N. Car.; position statement).

Bovey, R. W., E. Burnett, C. Richardson, M. G. Merkle, J. R. Baur and W. G. Knisel. 1974. Occurrence of 2,4,5-T and picloram in surface runoff water in the Blacklands of Texas. J. Environ. Qual. 3:61-64. (Agron., Soil Scientist, Agr. Eng., Plant Physiologist, and Hydraulic Eng., USDA-ARS, College Station, and Prof., Dep. Soil and Crop Sci., Texas A&M Univ., College Station; research conducted near Temple and Riesel, Texas).

This investigation was conducted to determine the concentration of 2,4,5-T and picloram in surface runoff water that may move from herbicide sprayed pastures and rangeland to untreated areas as a resul of each major rainfall following treatment.

Bovey et al 1974 (con't.)

A 1:1 mixture of the triethylamine salts of 2,4,5-T + picloram was sprayed 5 times at 1.12 kg/ha every 6 months on a native-grass pasture watershed. Soil, grasses and runoff water were analyzed periodically following herbicide treatment. Herbicide content in the Houston Black clay from May 1970 to May 1972 remained low (0 to 238 ppb). Herbicide content on grass was high (50 to 70 ppm) immediately after treatment, but degraded rapidly thereafter. Plant "washoff" was the main source of herbicide detected in runoff water. Concentration of herbicide was moderately high (400 to 800 ppb) if heavy rainfall occurred immediately after treatment, but low (<5 ppb) if major storms occurred 1 month or longer after treatment. No damage occurred to cotton (*Gossypium hirsutum* L.) or sorthum (*Sorghum bicolor* (L.) Moench) from either spray drift or subsequent runoff water in fields adjacent and below several herbicide-treated watersheds.

Grover, R. and A. E. Smith. 1974. Adsorption studies with the acid and dimethylamine forms of 2,4-D and dicamba. Can. J. Soil Sci. 54: 179-186. (Titles unknown, Research Station, Agr. Canada, Regina, Sasketchewan; research conducted in the Canadian Prairies).

The adsorption of acid and dimethylamine salts of 2,4-D and dicamba was studied on Canadian prairie soils and various other adsorbents, using slurry-type adsorption experiments. The amount of adsorption of both the acid and dimethylamine forms of the two herbicides was minimal. The results were explained on the basis of dissociation of the acidic and dimethylamine salts to the respective anionic forms in the near-neutral prairie soils. This conclusion was supported by (1) the strong adsorption of these herbicides to the anion-exchange resin but not to the catio-exchange resin; (2) the strong adsorption of the ^{14}C-dimethylamine cation to these soils; and (3) the leaching pattern of the ^{14}C-dimethylamine salts of both herbicides from soils and resins. Only the anionic species were eluted from columns containing soils and cation-exchange resin whereas only the ^{14}C-dimethylamine cation eluted from columns containing anion-exchange resin. Both forms of 2,4-D and dicamba were strongly adsorbed to activated charcoal, cellulose triacetate, and peat. There was little or no adsorption of these herbicides to montmorillonite and kaolinitic clays, cellulose powder, or wheat straw.

Maier-Bode, H. 1974a. The 2,4,5-T question. Health Aspects Pestic. 7:264. (72-1150). (Pflanzenschutz 45(1):2-6, 1972). (Credentials unknown; research conducted in Germany).

The evidence of harmfulness of the herbicide 2,4,5-T is reviewed in the light of recent legislation. The teratogenic effect of 2,4,5-T at high dosages, demonstrated in laboratory animals in the U.S. in 1969 is attributable to contamination of the lot of 2,4,5-T tested with 30 ppm of the highly toxic 2,3,6,7-tetra-chlorodibenzo-o-dioxin. At present, the manufacturers guarantee that the dioxin content in technical 2,4,5-T does not exceed 0.1 ppm. However, recent findings indicate that even 2,4,5-T containing not more than 0.1 ppm of 2,3,6,7-tetra-chlorodibenzo-p-dioxin can produce teratogenic effects in highly sensitive animals if administered orally at sufficiently high dosages. The likelihood of the ingestion of appreciable quantities of 2,4,5-T by man or animals under natural conditions is extremely remote, due to its relatively rapid degradation and low rate of application. Therefore, the West German Federal Advisory Council decided to permit the continued use of 2,4,5-T in agriculture, forestry and horticulture, with the reservation that aerial spraying requires permission from the regional government.

Maier-Bode, H. 1974b. Residues and side-effects of herbicides in forest protection. Pestic. Abstr. 7(2):57. (74-0257). (Anz. Schaedlingsk. Pflanzen-Umwelt-schutz 46(2):17-24, 1973). (Credentials unknown; research conducted in Germany).

Many of the herbicides currently authorized for use in forestry in West Germany cause problems with residues and possible side-effects. When applied as prescribed, these herbicides which include amitrole, chlorthiamid, dalapon, dichlobenil, paraquat, simazine, and 2,4,5-T are not harmful to terrestrial and aquatic flora and fauna, water quality, and wildlife. Damages to plants, aquatic organisms, and bees can be avoided by observing the directions for application. Dichlobenil, parathion, and sometimes DDT and chlorthiamid are harmful to bees; amitrole, dalapon, paraquat, simazine, and 2,4,5-T are not. Berries and mushrooms in treated forests usually contain residue levels too low to be harmful to humans. Groundwater contamination is negligible due to the low expenditure and the high adsorption applied near surface waters. Zero tolerance for amitrole residues in foods has been established. Very low residues and rapid elimination of chlorthiamid and dichlobenil were determined; and dalapon, 2,4,5-T, and paraquat were rapidly eliminated from humans and animals as well as from fruits.

Pokornts, Y. and K. Kulikova. 1974. Effects of pesticides on reservoir water. Pestic. Abstr. 7(8):509 (74-1874). (Gig. Sanit. 39(1):89-91, 1974). (Credentials unknown; research conducted in Russia).

Studies on the effects of pesticides on the organoleptic and biological properties of reservoir water and on general analytical methods are reviewed. Pesticides may contaminate reservoirs by infiltration or washout from treated farm lands, or by being discharged by pesticide manufacturing plants. Pesticides in water can be determined by colorimetry, gas chromatography, and thin-layer chromatography following extraction and concentration by means of activated carbon or by biological methods using algae, phytoplanktons, and fish as indicators. The odor threshold of most of the pesticides in water lies below 1 mg/liter; that of the major organochlorine pesticides varies from 0.13 μg/liter to 22 mg/liter; that of the major organophosphorus pesticides from 0.2 μg/liter to 1 mg/liter. Phenoxyacetic acid derivatives have odor thesholds ranging from 3 μg/liter to 3 mg/liter. The maximum allowable concentration of most of the pesticides, as determined by biological tests, lies below 1 mg/liter, but is as low as about 0.01 mg/liter for such preparations as atrazine, thiometon, and malathion. Bacteria are much more resistent to pesticides than plankton and fish.

Theraldsen, J. 1974. Water pollution due to spraying 2,4,5-T for brush control. Pestic. Abstr. 7:775 (Nor. Vet. Tidsskr. 85(5):277-279, 1973). (Credentials unknown; research conducted in Norway).

Water contamination was studied following repeated application of 2,4,5-T from helicopter onto brush along a canal. The 2,4,5-T residue in the water as measured immediately after the first spraying was 0.001 mg/kg, and a maximum concentration of 0.005 mg/kg was measured after the 5th spraying. The 2,4,5-T residue level in the water averaged 0.003 mg/kg, far below the ichthyotoxic limit of 1 to 6 ppm. Dense herbage covering the water surface prevented considerable contamination.

Webb, W. L., H. J. Schroeder, Jr., and L. A. Norris. 1975. Pesticide residue dynamics in a forest ecosystem: a compartment model. Simulation 24(6):161-169. (Res. Assoc. and Sim. Prog.-Math., Dep. Forest Manage., Oreg. State Univ., and Prof. Forester, USDA-FS, Corvallis, Oreg.; research conducted at Oregon State University).

Webb et al. 1975 (con't.)

This paper presents a computer model of the movement of pesticide residues in a forest ecosystem. As such, the paper deals primarily with the potential direct effects on target and nontarget organisms, but does not address the very long-term consequences of restructuring the vegetation in an ecosystem. Simulations using the model trace the movement of two herbicides (2,4,5-T and picloram) through two different environments, one typical of an Oregon forest and the other typical of southern California chaparral.

Plumb, T. R., L. A. Norris, and M. L. Montgomery. 1977. Persistence of 2,4-D and 2,4,5-T in chaparral soil and vegetation. Environ. Contam. and Toxicol., Bull. 17:1-8. (Titles unknown, USDA-FS, Pacific Southwest Forest and Range Exp. Sta., and Pacific Northwest Forest and Range Exp. Sta.; research conducted in southern California).

Radosevich, S. R. and W. L. Winterlin. 1977. Persistence of 2,4-D and 2,4,5-T in chaparral vegetation and soil. Weed Sci. 25:423-425. (Asst. Prof., Dep. Botany and Lecturer, Dep. Environ. Toxicol., Univ. of Calif., Davis; research conducted in San Diego and Monterey Counties, California).

The persistence of 2,4-D and 2,4,5-T was studied in the chaparral environment. Chamise (*Adenostoma fasciculatum* H. & A.), grass and forbs, soil surface litter, and soil were sampled for up to 360 days after herbicide (4.5 kg/ha) application. Over 50% of the 2,4-D and 2,4,5-T recovered was found on soil surface litter while 18 to 31% was found on vegetation. Much less herbicide (0.1 to 0.2%) was found in soil (0 to 5 cm) than in foliage or litter. No herbicide residues were found below the 0 to 5 cm soil sample zone. Herbicide residues on foliage and litter decreased rapidly (up to 93%) within 30 days after application but remained constant thereafter until winter rainfall began. Residues of both herbicides were evident in chamise foliage (0.01 to 0.02%) surface litter (0.01 to 0.03%), and soil (0.01%) up to 360 days after application.

II. Effects on Related Resources
A. Watershed Values
3. Soil, water and air contamination

SUMMARY AND CONCLUSIONS

A vital concern of spraying mesquite on watersheds is what happens to the herbicide. Some herbicides cannot legally be sprayed on certain kinds of watersheds or near bodies of water. The reasons for this action eminates from the presumed potential hazard of contamination. Winston and Ritty (1961) found that phenoxy herbicides, including 2,4,5-T and silvex, do not degrade into phenols, but rather are broken down into carbon dioxide, hydrochloric acid, and water by bacterial degradation. Many herbicides are detoxified by soil microorganisms (Thiegs, 1962; Newmark and Downing, 1965). However, other scientists (Whiteside and Alexander, 1960; Alexander, 1965b) indicated there was no evidence for microbiological degradation of 2,4,5-T.

Apparently persistence of phenoxy herbicides is dependent upon type and linkage of aliphatic side chains (Burger et al., 1962); acetic phenoxy's (e.g. 2,4,5-T) seem to be more persistent than proprionic acid derivatives (e.g. silvex). Degradation rates of 2,4,5-T, silvex, dicamba, and picloram in soil is proportional to the concentration of the herbicide applied (Altom and Stritzke, 1973).

Herbicide movement in soil is dependent upon chemical form applied (i.e. amine vs. ester) as well as amount and intensity of precipitation. Amine salts of 2,4,5-T and silvex leached to about 9-inch depths in a Pullman clay loam top soil, whereas the ester formulation remained within the top 3 inches (Wiese and Davis, 1964). Monuron and diuron are reasonably persistent in soil but the length of time that they persist depends on whether the soil is a muck or a fine sand (Newman and Downing, 1965). From rain immediately following application of herbicides, picloram and dicamba seem to run-off vegetated rangeland more than fallow land whereas 2,4,5-T losses from both situations are about the same (Trichell et al., 1968). However the amount lost was not extensive. Trichell et al., (1968) reported that the maximum loss through run-off of 2,4,5-T picloram or dicamba was 5.5%, and the average was 3%.

Picloram residues remain in soil longer than either 2,4,5-T or dicamba. Altom and Stritzke (1973) found that picloram residues remained in soil more than 100 days whereas 2,4,5-T and dicamba residues remained only 17 and 20 days, respectively. Picloram seems to be restricted to the upper 12 inches of soil but may persist 120 to 180 days (Scifres et al., 1971). Picloram usually dissipated from the soil profile within a year. Dicamba percolates to greater depths (4 to 5 ft) in the soil than picloram, but doesn't persist as long. Usually it is dissipated within 16 weeks (112 days), after application (Scifres and Allen, 1973). Tebuthiuron dissipates to about 10% or less from fine sandy loams and loamy fine sands within 14 months (Garcia et al., 1979).

A few studies involving lysimeters have been conducted to give us an indication of what happens to herbicides in the soil. Edwards and Glass (1971) found that most of 2,4,5-T removal in run-off occurred within the first 4 months after application and more than half of the loss occurred within 32 days. The astounding note, was that more than 25% of the entire loss was associated with one storm that occurred 21 days after application. Timing of herbicides application is quite critical.

Edwards and Glass found that the amount of 2,4,5-T was so small that groundwater was not contaminated.

Perhaps the greatest concern about herbicides is relative to the residues in aquatic environments. Herbicides may appear in aquatic ecosystems as the result of either direct application or run-off erosion from a watershed. Generally, herbicides are not as persistent in aquatic ecosystems as insecticides (Brown and Nishioka, 1967). Picloram diminished from a lentic system (lake or pond) within 6 months (Haas et al., 1970), most of which disappeared within 3 to 4 weeks (Hahn et al., 1970); however, where 1 lb of herbicide was sprayed directly on the pond, significant amounts were present 11 months after application (Haas et al., 1970). Scifres et al. (1971) reported no more than 1 to 2 ppb picloram in large ponds after dilution. Davis et al. (1968) reported the highest concentration of picloram in stream water was 0.37 ppm; after 16 months and 40 inches of rainfall, picloram was no longer detectable in the stream.

Elwell, H. M. and M. B. Cox. 1950. New methods of brush control for more grass. J. Range Manage. 3:46-57. (US-SCS Research and Okla. Agr. Exp. Sta.; study conducted at Red Plains Conservation Exp. Sta.; Guthrie, Okla.).

Paulsen, H. A. 1950. Mortality of velvet mesquite seedlings. J. Range Manage. 3:281-286. (Range Conservationist, USDA-FS; study conducted at Santa Rita Exp. Range, Tucson, Arizona).

The mesquite invasion of range lands in the Southwest has progressed rapidly in spite of a high rate of seedling mortality. A study of some of the factors affecting the mortality of velvet mesquite seedlings which emerged during the summer of 1948 on the Santa Rita Experimental Range showed that at the close of the second growing season, seedling mortality was 96, 94, and 47% under the following levels of protection: open to yearlong grazing by cattle and rodents, cattle exclusion, and protection from cattle and rodents.

Grazing by several species of native rodents present on the area was the most important factor in eliminating mesquite seedlings during the first two growing seasons. Previous work has shown that one of these, the Merriam kangaroo rat, helps to disseminate the seeds and is associated with the occurrence of great numbers of mesquite seedlings.

Subnormal rainfall, especially during the first summer growing season, and unusually low winter temperatures which occurred during the study period, were also important factors which contributed to the high mortality rate.

After two growing seasons, tap roots had developed to approximately 27 inches in length, and it is believed that those seedlings remaining alive at this time are capable of surviving subsequent droughts and developing into mature trees.

The increase in the mesquite stand which would result from the successful establishment of the remaining seedlings as shown in this study would be not less than 8 trees/acre/year.
As additional trees reach seed-bearing size, the rate of increase may be expected to become progressively more rapid and to intensify the problem even further.

Blair, B. O. 1951. Mesquite seed and seedling response to 2,4-D and 2,4,5-T. Bot. Gaz. 112:518-521. (Range Conservationist, USDA-FS; laboratory study conducted in Tucson, Arizona).

1. Seeds and seedlings of mesquite, *Prosopis juliflora* var. *velutina* (Woot.) Sarg., were cultured for 72 hr in aqueous solutions of 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) at concentrations of 1, 2, 5, 10, and 50 ppm. Suppression was measured and expressed in root and hypocotyl growth, and total fresh weight, in comparison with controls.

2. Seeds and young seedlings of mesquite were found to be responsive to 2,4-D and 2,4,5-T but not so sensitive as some other plants. Concentrations above 1 ppm show 2,4,5-T to be more toxic to mesquite than is 2,4-D. This has also been found true of foliage sprays applied to mature trees.

3. Suppression of both seeds and seedlings of 1 ppm of either herbicide shows the sensitivity of young plants to these compounds. Applications of much higher concentrations to mature plants as foliage sprays have not resulted in kills, indicating either lack of absorption and translocation or greater resistance of mature plant to these compounds.

Cable, D. R. and F. H. Tschirley. 1961. Responses of native and introduced grasses following aerial spraying of velvet mesquite in southern Arizona. J. Range Manage. 14(3):155-159. (Range Conservationists, USDA-FS, and USDA-ARS, respectively; study conducted at Santa Rita Exp. Range, Tucson, Arizona).

Herbage production of native perennial grasses and Lehmann lovegrass was compared on sprayed and unsprayed portions of a velvet mesquite-infested pasture.

In 1959, five growing seasons after the final spray treatment, mesquite mortality was 58% on the area sprayed with 3/4 lb of 2,4,5-T in each of the two successive years. On the area sprayed with 3/4 lb followed by 1/2 lb of 2,4,5-T, mortality was 36%; and on the area sprayed once, 2%. Defoliation in 1959 was 95, 86, and 17%, respectively, on the three treatment areas.

Cable, Tschirley 1961 (con't.)

Herbage production of native perennial grasses averaged almost twice as much on the sprayed as on the unsprayed area for the six growing seasons after the first spraying. Herbage production of lovegrass averaged more than three times as much on the sprayed area during the same time. No difference in perennial grass herbage production between the two areas sprayed twice was apparent.

Increased production of perennial grass on the areas sprayed twice more than paid the cost of spraying and seeding in the first three growing seasons after the first spraying. The slow rate of mesquite recovery indicates that the effects of the treatment will last several more years.

Roy, J. B. 1961. Roadside brush control with phenoxy herbicides in the New England states. Northeastern Weed Control Conf., Proc. 10:446-451.

(credentials unknown; study conducted throughout New England states).

The development and sales of 2,4-D and 2,4,5-T phenoxy herbicides during the past 15 years for brush control have provided the state highway departments, utilities, telephone companies, and towns with a tool that if properly used will benefit all. These public agencies with the use of these chemicals are able to give the public and the taxpayer better electrical and telephone service, and safer roads for each dollar spent than if hand and mechanical cutting of brush and weeds continued. The National Safety Council reports that one out of eight fatal automobile accidents is caused by poor visibility. Not all these accidents can be credited to uncontrolled vegetation; however, a significant percentage of these is caused by obstruction to vision from unwanted, uncontrolled brush. Brush that hinders visibility on curves, road crossings, and railroad crossings certainly should be eliminated for safety to the public. Also by the elimination of brush, areas are left for plowed snow, disabled vehicles have room to pull off the road for repairs, better drainage is obtained, and noxious weeds and brush such as poison ivy and ragweed are kept under control and even eliminated. The economics of chemical brush control is very favorable when compared with the cost of continual cutting and mowing.

Arnold, W. R. and P. W. Santelmann. 1966. The response of native grasses and forbs to picloram. Weeds 14:74-76. (Res. Asst. and Assoc. Prof., Dep. of Agron. Okla. State Univ., Stillwater, Okla.; laboratory study conducted at Okla. State Univ.).

In the greenhouse, picloram (4-amino-3,5,6-trichloropicolinic acid) prevented germination of sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), big bluestem (*Andropogon gerardi* Vitman), switchgrass (*Panicum virgatum* L.) and blue grama (*Bouteloua gracilis* (HBK) Lag.) when applied preemergence. When applied at 1.5 lb/acre or more at the two leaf stage in the greenhouse and field, picloram significantly reduced plant numbers of all species. Of the four species big bluestem appeared to be the most tolerant to picloram in the seedling stages. Germination was reduced when 2,4-D (2,4-dichlorophenoxyacetic acid) was applied preemergence to sideoats grama and the plant numbers of this species and switchgrass were reduced when treated at the two-leaf stage.

The application of picloram to established native range did not reduce forage production or desirable plant frequency. All treatments reduced forb production. Picloram gave very good control of western yarrow (*Achillea lanulosa* nutt.), white heath aster (*Aster ericoides* L. nutt.), and western ironweed (*Vernonia baldwini* Torr.). White sage (*Artemisia ludoviciana* nutt.) was resistant to 4 lb/acre of picloram.

Schmutz, E. M. 1967. Chemical control of three Chihuahuan desert shrubs. Weeds 15:62-67. (Assoc. Range Manage. Specialist, Agr. Exp. Sta., Univ. of Arizona, Tucson; study conducted in the Chihuahuan Desert).

Foliar and soil herbicidal treatments were made on creosotebush (*Larrea tridentata* (DC.) Cov.), tarbush (*Flourensia cernua* DC.), and whitehorn (*Acacia constricta* Benth.) near Tombstone, Arizona from 1957 to 1964. All herbicides were most effective when applied approximately 30 days after initiation of the summer rainy season. The herbicides 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) were about equal in effectiveness, but the relative susceptibility of the individual shrubs to the herbicides varied with treatment conditions. The acetic form of 2,4,5-T generally was more effective than the propionic; propylene glycol butyl ether, isooctyl, and tetrahydrofurfuryl esters more effective than pentyl. Foliar applications of 4-amino-3,5,6-trichloropicolinic acid (picloram) were most effective on whitehorn, intermediate on creosotebush, and least effective on tarbush.

Schmutz 1967 (con't.)

The most effective soil herbicidal treatments were 3-phenyl-1,1-dimethylurea (fenuron) and 3-(p-chlorophenyl)-1,1-dimethylurea (monuron). In general, effective control of dominant Chihuahuan Desert shrubs required 2 to 4 lb/acre of 2,4-D or 2,4,5-T, 0.25 to 1 lb/acre of picloram, or 2 lb/acre of fenuron or monuron.

Meyer, R. E. and T. E. Riley. 1969. Influence of picloram granules and sprays on whitebrush, Weed Sci. 17:293-295. (USDA-ARS, and Texas Agr. Exp. Sta., Plant Physiologist and Range technician; study conducted at Llano and Marble Falls (Edwards Plateau), Texas).

Whitebrush (*Aloysia lycioides* Cham.) near Llano and Marble Falls, Texas was treated at 19 dates with broadcast applications of the potassium salt of 4-amino-3,5,6-trichloropicolinic acid (picloram) as the 2% granules. At Llano, the average percentages of whitebrush plants killed with 1, 2, and 4 lb/acre rates of picloram granules at five dates were 18, 52, and 87; however, at three dates, the 3 lb/acre treatment killed 98% of the plants. Picloram granules were applied at 15 dates at Marble Falls where 1, 2, 3, and 4 lb/acre rates averaged 17, 43, 68 and 79% of the whitebrush plants killed, respectively. Picloram was most toxic when applied during the cooler months, particularly when application was soon followed by rains. Broadcast sprays of the potassium salt of picloram were included at two dates and were more effective than granules. Most individual whitebrush plants were killed by one-third tablespoon of the 10% granules, or by 2 tablespoons of the 2% granules of picloram applied in an area 2 ft in diameter at the base of the stem

Brock, J. H., C. J. Scifres, and R. R. Hahn. 1970. Influence of herbicides on weed control and the establishment of grasses in rangeland reseeding, p. 46-52. Texas Agr. Sta. Prog. Report 2811. In, Brush Research in Texas. Texas Agr. Exp. Sta. Consol. PR 2801-2828. (Res. Assoc., Prof., and Res. Assoc., Dep. of Range Science, Texas A&M Univ.; study conducted near Dumont, Rolling Plains Texas).

Brock et al. 1970 (con't)

MCPA and MCPB resulted in the lowest levels of weed control in reseeded grasses from a May 23, 1969, application. Best weed control from May 23 treatments resulted from applications of 1.0 lb/acre of 2,4-D and 1.0 lb/acre of picloram. MCPA and MCPB caused a greater reduction in weed numbers when applied June 11, 1969, to a similar area, than when applied May 23. Little difference in results was found between application dates among the other treatments.

None of the May 23 treatments caused a reduction in grass stand. All treatments applied June 11, except dicamba at 0.5 lb/acre bromoxynil at 0.5 and 1.0 lb/acre, and 2,4-D at 1.0 lb/acre caused a slight reduction in grass stand. On October 1, grass damage assessed as degree of lodging was most apparent in plots in which picloram was included as a treatment.

Gibson, J. W. and J. B. Grumbles. 1970. Aerial application of herbicides for control of whitebrush and associated species. Down to Earth 26(2):1-4. (Former Res. and Development Specialist, Okla., and Res. and Development Specialist, Dow Chemical Company; study conducted in Marble Falls, Edwards Plateau Texas).

Mesquite was controlled best by 2 lb/acre of picloram + 0.5 lb/acre 2,4,5-T applied in the fall; this treatment killed 24% of the plants and killed the above-ground stems of another 23%. The spring and fall 3 lb/acre picloram treatments killed 25% (1 of 4 plants) and 13% of the mesquite plants, respectively. Thus, some mesquite can be killed in the fall. Unfortunately, no treatment containing 2,4,5-T was applied in the spring when mesquite is usually controlled best.

Martin, S. C., S. J. Shellhorn, and H. M. Hull. 1970. Emergence of fourwing saltbush after spraying shrubs with picloram. Weed Sci. 18:389-392. (Principal Range Scientist, USDA-FS, Botanist and Plant Physiologist USDA-ARS; study conducted at Santa Rita Exp. Range, Tucson, Arizona).

Aqueous sprays of 4-amino-3,5,6-trichloropicolinic acid (picloram) (1 lb a.e./100 gal) were applied to individual plants in stands of burroweed (*Haplopappus tenuisectus* (Greene) Blake) and creosotebush (*Larrea tridentata* (DC.) Coville) August 27 to 31, 1965, to prepare

Martin et al. 1970 (con't.)

the areas for seeding to fourwing saltbush (*Atriplex canescens* (Pursh) Nutt.). By July 1967, 99% of the burroweed was dead, but 90% of the creosotebush was still alive. Samples of the surface 0.5 inch of soil, taken February 1, 1966, were planted to fourwing saltbush. Emergence and growth of fourwing saltbush were seriously reduced on soil taken from under the sprayed burroweed crowns. Growth of fourwing saltbush seedlings was retarded on soils from beneath sprayed creosotebushes, but emergence was not reduced significantly. The surface soil under sprayed burroweed crowns contained 0.11 ppm picloram 2 years after treatment, but the picloram test was negative on soils from the creosotebush area.

Cronin, E. H. and D. B. Nielsen. 1972. Controlling tall larkspur on snowdrift areas in the subalpine zone. J. Range Manage. 25:213-216.

Plant Physiologist, USDA-ARS, and Assoc. Prof. of Agr. Eco., Utah State Univ., Logan, Utah; study conducted in Utah).

Repeated annual applications of 2,4,5-T ((2,4,5-trichlorophenoxy) acetic acid) or silvex ((2-(2,4,5-trichlorophenoxy) propionic acid) reduced the density of tall larkspur (*Delphinium barbeyi* (Huth) Huth) below a level that is potentially dangerous to grazing cattle. Killing tall larkspur and other forbs resulted in a plant community dominated by grasses. The dominant species of grass depended on whether the treated plot was grazed by cattle. Letterman needlegrass (*Stipa lettermanii* Vasey) dominated when plots were protected from grazing cattle. Reinvasion of treated areas by tall larkspur and the unpalatable weedy species occurred more rapidly on grazed plots than on ungrazed plots.

Halifax, J. C. and C. S. Scifres. 1972. Influence of dicamba on development of range grass seedlings. Weed Sci. 20:414-416.

(Grad. Res. Asst. and Assoc. Prof. Dep. of Range Sci., Texas A&M Univ., College Station, Texas; laboratory study conducted at Texas A&M).

Seedlings of switchgrass (*Panicum virgatum* L. 'Blackwell'), sideoats grama (*Bouteloua curtipendula* (Michx.) Torr. 'Premier'), and native vine mesquite (*Panicum obtusum* H. B. K.) tolerated 0.28 kg/ha of 3,6-dichloro-*o*-anisic acid (dicamba) applied preemergence. After emergence, sideoats grama tolerated 0.56 kg/ha dicamba. Preemergence or postemergence applications of 1.12 and 2.24 kg/ha severely retarded shoot production of all three species. Soil residues in

Halifax and Scifres 1972 (con't.)

the surface 2.5 cm reduced root production of grass seedlings, whereas placement of dicamba 7.6 or 15.2 cm deep was not detrimental. All grass species germinated and grew for 21 days in soil containing up to 63 ppb of dicamba without reduction in shoot production. Overall order of susceptibility to dicamba was ranked as vine mesquite>switchgrass>sideoats grama.

Scifres, C. J. and J. C. Halifax. 1972. Development of range grass seedlings germinated in picloram. Weed Sci. 20:341-344. (Asst. Prof. and Grad. Res. Asst., Dep. of Range Sci., Texas A&M Univ., College Station, Texas; laboratory study conducted at Texas A&M).

Picloram (4-amino-3,5,6-trichloropicolinic acid) did not influence germination but differentially regulated postgermination growth of range grass seedlings. Radicle elongation of buffalograss (*Buchloe dactyloides* (Nutt.) Elgelm.), sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), and switchgrass (*Panicum virgatum* L.) in petri dishes was reduced by 125 ppb picloram, whereas shoot elongation was not retarded by 1,000 ppb. Buffalograss, sideoats grama, and switchgrass seedlings, germinated in soil containing 500 ppb picloram, were usually not reduced in topgrowth production. However, topgrowth production of Arizona cottontop (*Digitaria californica* (Benth.) Henr.) and vine mesquite (*Panicum obtusum* H. B. K.) was reduced 125 to 250 ppb of picloram in soil. Relative tolerance to picloram was ranked buffalograss, sideoats grama> switchgrass>vine mesquite, Arizona cottontop.

Bovey, R. W., R. E. Meyer, and E. C. Holt. 1974. Tolerance of bermudagrass to herbicides. J. Range Manage. 27:293-296. (Agronomist and Plant Physiologist, USDA-ARS, and Professor, Dep. Soil and Crop Science, Texas A&M University, College Station, Texas; research was conducted near College Station, Texas).

Herbicides 2,4-D, 2,4,5-T and dicamba applied in spring or fall usually did not reduce yields of bermudagrass. When applied during dry periods, picloram reduced density and yield of bermudagrass. Degree of bermudagrass injury was directly related to rate of herbicide. "Common," "Coastal," and "Coastcross-1" varieties responded similarly to each herbicide studied. Kleingrass, a new forage grass growing in the plot area, was tolerant of all herbicide treatments, including picloram.

Niering, W. A. and R. H. Goodwin. 1974. Creation of relatively stable shrublands with herbicides: arresting "succession" on rights-of-way and pastureland. Ecology 55:784-795. (Botanists, Connecticut College, New London, Connecticut; study conducted at Connecticut Arboretum).

Two decades of selective-use herbicide management on a demonstration right-of-way within the Connecticut Arboretum has resulted in a mosaic of relatively stable shrub communities and less stable herblands within the central hardwoods forest region. Areas of continuous dense shrub cover have resisted tree invasion for at least 15 yr. On abandoned pastureland shrub clones of *Gaylussacia baccata, Smilax rotundifolia,* and *Vaccinium vacillans*, from which associated tree growth was selectively removed, were analyzed for subsequent tree invasion. They have remained essentially stable for 5 yr. with virtually no tree invasion in the closed clones, as compared to pronounced invasion of the graminoid periphery of the clones. This stability can be explained in terms of Egler's "initial floristic composition" hypothesis for vegetation change, as explained in this paper. The ability of shrub communities to resist tree invasion has always belied the so-called classical concepts of succession and climax, as have the findings of other investigators. The substitution of the term "vegetation development" for "succession" and "relative stability" for "climax" would stimulate a more creative interpretation of vegetation dynamics.

Creating relatively stable shrub communities by the selective use of herbicides has practical application in right-of-way and wildlife habitat management, naturalistic landscaping, and the maintenance of habitat diversity.

Tomkins, D. J. and W. F. Grant. 1974. Differential response of 14 weed species to seven herbicides in two plant communities. Can. J. Bot. 52:525-533. (Credentials unknown; laboratory study conducted at Macdonald Campus of McGill Univ., Anne de Bellevue, Quebec).

The responses of 14 weed species to seven different herbicides were compared. The species included five monocots: *Agropyron repens* (L.) Beauv., *Agrostis alba* L., *Carex gracilescens* Mack., *Phleum pratense* L., and *Poa pratensis* L.; and nine dicots: *Ambrosia artemisiifolia* L., *Aster cordifolius* L., *Fragaria virginiana* Duchesne, *Oxalis europaea* Jord., *Pastinaca sativa* L., *Solidago canadensis* L., *S. nemoralis* Ait., *Taraxacum officinale* Weber, and *Vicia cracca* L. A principal component analysis revealed that species responses to four auxin herbicides ((2,4-dichlorophenoxy) acetic acid (2,4-D), Tomkins and Grant 1974 (con't.)

picloram, picloram + 2,4-D, and 2,4-D + (2,4,5-trichlorophenoxy) acetic acid (2,4,5-T)) were very similar, although picloram was more effective in eliminating *Aster cordifolius, Fragaria virginiana, Solidago nemoralis,* and *Vicia cracca.* Auxin response differed markedly between monocots and dicots, whereas life-form was important in determining the response of the species to paraquat, simazine and diuron treatments. Response to herbicide treatment was similar in both pioneer and mature old-field communities. However *Phleum pratense* and *Poa pratensis* were susceptible to all auxin treatments in the pioneer community but were resistant to the same treatments in mature fields.

Cwik, M. J. and J. D. Dodd. 1975. Vegetation changes on an old rice field following herbicide treatment. Southwest. Nat. 20:379-389. (Titles unknown, Dep. Range Science, Texas A&M University, College Station, Texas; research was conducted on the World Wildlife Fund Attwater's Prairie Chicken Refuge, Colorado, Co., Texas).

In late spring 1971, 1 lb/acre (2,4-dichlorophenoxy) acetic acid (2,4-D) and 1 lb/acre 3,6-dichloro-o-anisic acid (dicamba), salt forms, were applied to separate plots of vegetation in an old rice field in the Coastal Prairie Association of Texas. Forb densities decreased and species composition changed during summer and fall on untreated plots. Treated plots had significantly lower forb densities during summer and fall. No significant difference in forb densities occurred between the two herbicide treatments. Grass seedling densities were over 200% higher on treated plots during summer than on untreated plots. Total herbage yield, at the end of the growing season, was similar on all plots, but grass herbage yields were over 23% greater on the herbicide treated plots than on untreated plots.

Wendel, G. W. and F. C. Cech. 1975. Recovery of herbicide-damaged eastern white pine. Tree Planters Notes 26(4):18-21. (Research Forester, USDA-FS, Northeastern Forest Exp. Sta., Parsons, W. Virginia and Professor, Forest Genetics, W. Virginia Univeristy, Morgantown; research conducted on the Fernow Exp. Forest near Parsons, W. Virginia).

Mistblower applications of 2.4 lb of 2,4,5-T acid in 6 gal of fuel oil/water per acre were effective in releasing 3 to 4 year old white pine from a dense stand of blackberries, greenbriars, and hardwood sprouts.

Young, A. L., C. E. Thalken, and W. E. Ward. 1975. Vegetative assessment of test area C-52A, p. 11-27. In, Studies of the ecological impact of repetitive aerial applications of herbicides on the ecosystem of test area C-52A, Eglin AFB, Florida. Final Report ending December, 1974. AFAIL-TR-75-142 (Air Force Armament Laboratory. Eglin Air Force Base, Florida). (Captain (Ph.D.), Major (V.C.), and Lt. Col. (Ph.D.) of USAF, respectively; study area Eglin AFB, Florida).

Steinert, W. G. and J. F. Stritzke. 1977. Uptake and phytotoxicity of tebuthiuron. Weed Sci. 25:390-395. (Grad. Res. Asst. and Assoc. Prof., Dep. of Agron., Okla. State Univ., Stillwater, Okla.; laboratory study conducted at Okla. State Univ.).

Differences in the phytotoxicity of tebuthiuron (N-(5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl)-N,N'-dimethylurea) to nine plant species were observed on the basis of calculated GR_{50} value of 0.016 ppmw was the most susceptible and corn (*Zea mays* L. 'Gold Rush') with a GR_{50} value of 0.436 ppmw the last susceptible. There was some growth suppression with foliar application but primary activity on all species was attributed to root uptake. The most significant translocation of labeled tebuthiuron was to the tops of common ragweed (*Ambrosia artemisiifolia* L.) plants treated through the nutrient solution where 24.5% of the total amount recovered was detected in the top of rye (*Secale cereale* L. 'Elbon') plants with the same treatment. With both species, more than 90% of the radioactivity recovered following foliar treatments was still in the treated leaf after 24 hr. Less than 5.5% of the recovered activity for both species was in the tops less than 3% in the roots, and less than 1.5% was in the nutrient solution.

Dahl, B. E., R. E. Sosebee, J. P. Goen and C. S. Brumley. 1978. Will mesquite control with 2,4,5-T enhance grass production? J. Range Manage. 31:129-131. (Prof., Assoc. Prof. and Res. Assoc., Dep. of Range and Wildlife Mgt., Texas Tech Univ. Lubbock, Texas; study conducted in the Rolling Plains of Texas).

Dahl et al. 1978 (con't.)

Both honey mesquite density and percent of plants dead the year of aerial spraying with 2,4,5-T proved to be major factors influencing perennial grass production. Sites with sparse honey mesquite stands and very dense stands (over 50% canopy cover) yielded little extra grass after 2,4,5-T application. Heavy mesquite foliage probably prevented adequate leaf coverage with 2,4,5-T in dense stands, and in sparse stands mesquite competed little with the herbaceous plants. Increased perennial grass production of about 540 lb/acre/year would be necessary over a 5-year period to break even with a $4.60/acre aerial application of 2,4,5-T. With honey mesquite cover of 30%, a plant kill over 80% the year of application was required to provide a 540 lb/acre/year grass increase. However, a 90% kill would provide nearly 750 lb/acre/year extra perennial grass. Thus, paying particular attention to optimum environmental factors and proper timing for the 2,4,5-T application can pay big dividends.

Sosebee, R. E., W. E. Boyd, and C. S. Brumley. 1979. Broom snakeweed control with tebuthiuron. J. Range Manage. 32:179-182. (Assoc. Prof., Grad. Res. Asst. and Res. Assoc., Dep. of Range and Wildlife Manage., Texas Tech Univ., Lubbock, Texas; study conducted in High Plains of Texas and New Mexico).

Broom snakeweed was effectively controlled for at least 3 years with 0.6 kg a.i./ha (80% wettable powder) tebuthiuron on the Southern High Plains. Total herbage production decreased following broom snakeweed control, but grass yield generally increased when the snakeweed was removed. Broom snakeweed control was not affected by application time during the year. However, grass production was significantly reduced for three growing seasons by application of tebuthiuron in May. Grass yield was not affected by applications in either November or January.

SUMMARY AND CONCLUSIONS

The effect of spraying mesquite on associated species depends largely upon the species present and the kind of herbicide used. Phenoxy herbicides (which includes 2,4,5-T and silvex) generally affect a wide array of herbaceous broadleaf plants, but they do not generally affect grasses. Conversely, 2,4,5-T does not detrimentally affect as many broadleaf herbaceous plants as other phenoxy herbicides. The spectrum of control of herbaceous plants is increased with bipyridylium quarternary ammonium salts (which includes picloram), benzoic acids (which includes dicamba),and substituted ureas (which includes fenuron, monuron, and tebuthiuron). Substituted ureas are often used as soil sterilants, at high rates, around industrial sites.

Grasses growing in association with mesquite are generally not adversely affected by spraying mesquite Dahl et al.,(1978); therefore herbaceous composition may only slightly be altered. Although tall larkspur (*Delphenium barbeyi*) does not grow in association with mesquite (but rather in subalpine regions of western North America), its density is reduced by spraying 2,4,5-T or silvex (Cronin and Nielsen, 1972). *Aster cordifolius, Fragaria virginiana, Solidago nemoralis,* and *Vicia cracca* were eliminated from both pioneer and mature plant communities with either picloram or a combination of 2,4-D (2,4-dichlorophenoxy acetic acid) plus 2,4,5-T (Tomkins and Grant, 1974). In the same study, *Phleum pratense* and *Poa pratensis* were eliminated from the pioneer community but they were not affected in the mature community when they were sprayed.

Brock et al. (1970) found that neither dicamba or picloram sprayed (0.5 lb. a.e./acre) for weed control reduced grass seedlings (El Reno sideoats grama, Premier sideoats grama, sand bluestem, green sprangletop, switchgrass, Indiangrass, little bluestem, and Caucasian bluestem), following reseeding. Rates of 1.0 lb a.e./acre reduced the number of grass seedlings (Table 5), although the reductions were probably not significant. All herbicide rates of either dicamba or picloram substantially reduced forb production.

Herbicide tolerance by grasses generally increases with stage of growth. However grasses differentially respond to type and rate of herbicide used (Halifax and Scifres, 1972; Scifres and Halifax, 1972). Seedlings of vine mesquite, switchgrass, and sideoats grama are tolerant to dicamba, in descending order of susceptibility (Halifax and Scifres, 1972). Seedlings of buffalograss, sideoats grama, switchgrass, vine mesquite and Arizona cottontop are tolerant to picloram, in descending order (Scifres and Halifax 1972). Application of picloram (1 to 4 lb a.e. or a.i./acre) to established native rangeland did not reduce forage production or desirable plant frequency (Arnold and Santelmann 1966), but it did control some undesirable forbs. Desirable forage plants respond similarly to tebuthiuron (Steinert and Stritzke, 1977; R. E. Sosebee, unpublished data). Results obtained from applying tebuthiuron to either mesquite or broom snakeweed indicates that blue grama, sideoats grama, hooded windmill, sand dropseed, and others are enhanced while buffalograss, sand lovegrass, etc. are affected detrimentally (R. E. Sosebee, unpublished data).

Half-shrubs and woody plants are generally more susceptible to herbicides than other grasses. Broom snakeweed can be practically

Table 5. Influence of dicamba and picloram on grass seedlings and undesirable forbs (weeds). Herbicides were applied June 11, 1969. Evaluations presented were made July 24, 1969. (Brock et al. 1970).

Herbicide	Rate (lb a.e./acre)	Grass Seedlings (No./ft²)	Reduction in Weeds (Percent of Check)
check	---	2.3 1/	--
dicamba	0.50	2.7	32 1/
dicamba	1.00	1.7	50
picloram	0.25	2.2	32
picloram	0.50	2.2	42
picloram	1.00	1.8	55

1/ No statistics presented.

eliminated from a community with tebuthiuron at rates of 0.5 to 1.0 lb. a.i./acre (Sosebee et al., 1979). Gibson and Grumbles (1970) reported that picloram plus 2,4,5-T is more effective in controlling associated species than it is in controlling mesquite. Rates of 1 lb a.e./acre eliminated 75 to 100% of whitebrush, pricklypear, and tasajilla (Table 6). Whitebrush is relatively susceptible to picloram, 2,4,5-T and picloram plus 2,4,5-T; it is particularly susceptible to picloram granules (Meyer and Riley, 1969). Similarly, winged elm is killed relatively easy with picloram, 2,4,5-T, or picloram plus 2,4,5-T (Elwell, 1968).

Creosotebush, tarbush, and whitethorn (*Acacia constricta*) are differentially affected by 2,4,5-T, silvex, picloram, fenuron or monuron (Schmutz, 1967). Picloram (0.25 to 2.0 lb a.e./acre) was the most effective liquid herbicide used to control the Chihuahuan shrubs, whereas the phenoxy herbicides were less effective. Soil applied substituted ureas were most effective in killing the Chihuahuan desert shrubs (Schmutz, 1967). Burroweed (*Haplopappus tenuisectus*) is more easily killed with picloram (1 lb a.e./100 gal solution) than creosotebush (Martin et al., 1970). Germination of fourwing saltbush (*Atriplex canescens*) seed was seriously reduced following burroweed sprayed with picloram (Martin et al., 1970). Seedling mesquite is suppressed by relatively low rates of 2,4,5-T (Blair, 1951).

Extensive studies using 2,4,5-T, 2,4-D and picloram (herbicides used by the military) have been conducted at Eglin Air Force Base, Florida. Repeated applications and massive quantities (not specified, but other information indicates rates in excess of 100 lb were sprayed 1962 through 1970 (Young et al., 1975). Grasses (*Panicum lanuginosum* and *P. virgatum*) were the first plants to become established

Table 6. Percent whitebrush and associated species killed by May (spring) and October (fall) 1965, treatments at Marble Falls, Texas, as rated September 1967 and 1969. (Gibson and Grumbles, 1970).

		Species										
Chemical	Rate lb/A	White-brush 1967	Agarito 1969	Bluebush Condalia 1969	Cedar Elm 1969	Honey Mesquite 1969	Live Oak 1969	Lotebush Condalia 1969	Prickly-Pear 1967	Small Dogweed Yucca 1969	Tasajillo 1967	Texas Persimmon 1969
Picloram Spring[b,c,d]	1	66	0	0	0	0	0	0	86	0	100	3
Picloram Spring[c,d]	2	87	0	7	0	0	0	0	100	14	90	0
Picloram Spring[b,c,d]	3	98	0	8	100	25	0	0	100	0	100	1
Picloram Spring[b,c,d]	4	96	0	3	48	0	65	5	100	0	--	0
Picloram + 2,4,5-T Fall[b,d]	2+0.5	85	0	0	0	24	0	6	67	0	100	2

[a] X-77 + diesel oil added
[b] P-400 added
[c] NORBAK particulating agent
[d] Picloram applied as TORDON 22K herbicide
[e] Picloram applied as TORDON 101 Mixture (+2,4-D) and TORDON 22K herbicide

following spraying. Annual forbs (*Dioda teres* and *Hypericum gentianoides*) soon invaded the moist communities. Climax community of pine trees (*Pinus* sp.) soon occupied the area.

The above discussion indicates that aerial spraying 2,4,5-T generally has little adverse affect on vegetation growing in association with mesquite, whereas either picloram or picloram plus 2,4,5-T effectively reduces or kills much of the associated vegetation.

Bramble, W. C. and W. R. Byrnes. 1958. Use of a power-line right-of way by game after chemical brush control. Game News (September): 19-25. (Professor and Acting Head, School of Forestry, and Instructor, School of Forestry, Pennsylvania State University, research was conducted in central Pennsylvania).

It is becoming evident from controlled research studies that chemical spraying can be carried out on rights-of-way so as to remove the brush and provide for efficient maintenance of the power facilities, and also to create food and cover conditions conducive to increased game usage. The new cover types created on the right-of-way following spraying act both to furnish edge effects and to diversify the cover types in close position to each so that the game can travel from one to the other for necessary life activities. While it is true that broadcast spraying removes certain shrubs which could be maintained by selective basals, where the game species favored in a given area are best provided for by a grass-herb cover, broadcast spraying may be a desirable type of treatment from the viewpoint of the game manager. Such sprays should be done thoroughly so as to kill brush in one treatment, and then, selective basals be used as follow-up sprays to remove unkilled woody brush and to provide continued maintenance. Basally sprayed rights-of-way produce a tight cover that is relatively inexpensive to maintain and will be highly satisfactory both for the utility and for the game manager or sportsmen. It should be recognized that these rights-of-way represent minor land areas among our extensive game lands and should not be expected to provide, for example, winter browse for a large herd of deer. Such forage will have to be created by extensive cutting for wood products. However, rights-of-way, when maintained under chemical spraying, certainly are capable of bearing more than their fair share of the food and cover requirements for game species.

Box, T. 1964. Changes in wildlife habitat composition following brush control practices in south Texas. North Am. Wildl. Conf., Trans. 29:432-438. (Range Research Scientist, Welder Wildlife Foundation, and Professor, Dep. Agronomy, Texas Tech University, Lubbock; research conducted on the Welder Wildlife Refuge, Sinton, Texas).

Box 1964 (con't.)

Brush control is an established range improvement practice in South Texas. The land is almost totally privately owned, and the owners must make a profit from their ranching operation. Therefore, brush control is likely to increase rather than decrease in the future.

Brush removal affects game populations through change in cover and food availability. Research must answer the questions of the amount and kind of both food and cover that is necessary for the maintenance of optimum wildlife populations. Systems of brush management can be designed that will allow for rotational control to provide adequate regrowth for cover. Brush control methods can be selected that will yield the best possible combination of food and cover plants on each soil type. Both the rancher and the game manager must think in terms of a brush management program other than brush eradication. With proper research information and advanced planning, brush ranges may be managed for increased yields of both wild and domestic animals. The problem is simply one of keeping the correct successional stages present in the desired proportions and distributions.

Box, T. and J. Powell. 1965. Brush management techniques for improved forage values in south Texas. North Am. Wildl. Conf., Trans. 30:285-296. (Range Research Scientist, Welder Wildlife Foundation and Professor, Dep. Agronomy, Texas Tech University and Research Fellow, Welder Wildlife Foundation, Texas Tech University; research conducted on the Welder Wildlife Foundation, Sinton, Texas).

Much of South Texas rangelands is covered by a chaparral complex that is considered relatively unpalatable to livestock and game animals. Large acreages of this brushland are cleared annually by various techniques with the expressed goal of eradication of the brush cover. Such complete removal of brush not only destroys game habitat, but removes the woody species as forage plants.

During the summer of 1963, 5 treatments of commonly used brush techniques were established on clay and sandy loam soils of the Rob and Bessie Welder Wildlife Refuge in order to study the relative merits of brush management techniques. Methods used were mowing, roller chopping, clearing with a bulldozer and K-G blade, rootplowing, and raking.

All methods reduced cover significantly. The root-plowed areas and the root-plowed and raked plots reduced the brush populations to the point where it had no significant value for forage. Mowing of brush increased forage values 8 fold over the check, roller chopping

Box and Powell 1965 (con't.)

increased brush forage values 6 fold, and removing with a K-G blade increased forage values 4 fold on clay soils. On sandy loam soils, roller chopping and K-G blade removal of brush increased its value almost 2 fold, root-plowing and root-plowing and raking reduced forage values almost to zero, and mowing was not tested.

Browse preference values were increased on all species of woody plants by treatments used. Highest preference values were for plants that resprouted vigorously after their tops had been removed.

Brush management, or control of woody plants, appears to be more desirable from a livestock-game standpoint than attempted eradication of brush on South Texas ranges. Removal of brush tops by relatively inexpensive methods increased forage values and preference ratings of brush plants and did not permanently destroy wildlife cover.

Ryland, G. 1965. Wildlife thrives in rice land. White River J. August 21, 1965. Arkansas. (Farmer, southeastern Arkansas).

Chamrad, A. D. and T. W. Box. 1968. Food habits of white-tailed deer in south Texas. J. Range Manage. 21:158-164. (Research Fellow and Professor, Welder Wildlife Foundation and Texas Tech University, Lubbock; research conducted on the Welder Wildlife Refuge, Sinton, Texas).

White-tailed deer were primarily grazers, rather than browsers, during the winter-spring periods of 1963, 1964, and 1965, in south Texas. There were only minor differences in distribution of major forage classes in deer diets from distinct range site groups, but major differences existed in species composition of diets in relation to site. Complexity of diet reduced the importance of any one or several species in the diet. Among high priority forage species, perennials were more important than annuals. Deer food habits varied according to availability and phenology of range vegetation, and were further modified by forage preferences.

Davis, R. B. and C. K. Winkler. 1968. Brush vs. cleared range as deer habitat in southern Texas. J. Wildl. Manage. 32:321-329. (Titles unknown, Texas A&I University, Kingsville, and Texas Parks and Wildlife Dep., Rockport, Texas; research conducted in Uvalde, Frio,

Davis and Winkler 1968 (con't.)
Dimmit, Zavala, and Webb, Co., Texas).

A study made in the Rio Grande Plain of Texas to compare native brush ranges with root-plowed ranges as habitat for white-tailed deer (*Odocoileus virginianus*) consisted of three phases: (1) a general study of plant phenology to determine the periodicity of important browse species, (2) a comparison of forage available with that eaten by deer on brush ranges and rootplowed ranges, and (3) a study of deer behavior and movements on adjacent areas of native brush and rootplowed rangeland. Forage production throughout southern Texas was affected by duration and intensity of winter cold, grading from severe effects in the northern portions of the region to practically none at the southern limits. Browse, the major deer food in the area, was more abundant on brushy ranges than on rootplowed ranges reseeded to grasses; but forbs, the preferred deer food, were about equally abundant on the two ranges. Deer preferred to inhabit brush rather than rootplowed ranges, particularly under drouth conditions, and this preference is related to the greater availability of fruits and leaves of brush species on brush ranges.

Klebenow, D., D. Woodard, and M. Bell. 1970. White-tailed deer research in south Texas, p. 24. In, Noxious Brush and Weed Control Research Highlights. ICASALS Spec. Report No. 40. Texas Tech Univ., Lubbock. (Assist. Prof., Res. Assoc., and Grad. Student, Dep. Range and Wildlife Manage., Texas Tech Univ.; research conducted near Sinton, Texas).

Aerial counts of the deer on the Pat Welder Ranch at Sinton, Texas, indicated a deer density of one deer per 36 acres. Counts were made in February, 1970, and will be repeated in February, 1971. These counts are an attempt to determine the deer population before brush is controlled on the ranch. Mr. Welder intends to initiate a brush control program as part of the ranch operation. The objective is to develop a management scheme that will maximize income from livestock and wildlife. An experiment will be carried out using different patterns of brush control.

A study is underway on the deer food habits before brush control. The analysis of plant material in feces is the technique being used. Field samples are being gathered; no analyses have been made to date.

Byard, M. E. and D. A. Quinton. 1973. White-tailed deer, brush control, and grazing systems, p. 30. In, H. A. Wright and R. E. Sosebee (ed.), Noxious Brush and Weed Control Research Highlights. Vol. 4. Texas Tech University, Lubbock. (Grad. Asst. and Asst. Prof., Dep. Range and Wildlife Manage., Texas Tech University; research conducted near San Angelo, Texas).

Research is currently under way to evaluate the effects of brush control coupled with high intensity---low frequency (HILF) grazing practices on white-tailed deer movements, diets, and nutrition.

Two, 2 mile Hahn census lines through each of four pastures in the grazing system of the Crooked River Ranch adjacent to the Clear Fork of the Brazos River have been established. These lines will provide census data throughout the year. This data will give some indication of deer usage relative to cattle pressure and brush control measures.

Fecal collection plots have been established to compare deer diets among habitat types as well as in relation to cattle usage of particular habitat types. Seasonal forage utilized by deer will be gathered and chemically analyzed for its nutritive contents.

Horejsi, R. G. 1973. Influence of brushlands on white-tailed deer diets in northcentral Texas. M.S. Thesis. Texas Tech University, Lubbock. 69p. (Grad. Asst; Dep. Range and Wildlife Manage., Texas Tech University; research conducted near Stamford, Texas).

Comparison of rumen and colon contents showed a correlation coefficient of 0.89. Prickly pear was the dominant item in both sections of the digestive tract. Ironwood, mesquite, and mistletoe fragments appeared in nearly equal proportions within the rumens and colons. Differences in proportions of food items in various parts of the digestive tract can be attributed to nomadic nature of the animals, time lapse of food passage through the animals' systems, and differential digestion.

Microscopic examination of fecal material appeared to provide a good indication of the major forage species consumed by white-tailed deer. When limitations such as time lapse for food digestion and digestibility coefficients are realized the technique can be used with reliability to determine dietary habits.

Horejsi 1973 (con't.)

Results from this research suggest that diets of white-tailed deer on the study area are a transition between those reported from northern and southern areas. Data showed that browse accounted for more than 50% of the yearly diets on all treatment areas except two. These two areas had undergone extensive control programs to remove all brush. In both areas forbs represented a dominant portion of the seasonal diets of deer.

Problems arising with brush control programs and wildlife management center primarily around cover removal and not forage changes. Deer must have escape and resting cover for survival. Indications from this study are that total brush erradication over extensive areas will eliminate deer. Selective control practices or pattern arrangements will allow maintenance of wildlife populations. This fact is also demonstrated by observing utilization of the 1972 dozed upland. Deer used this area at night but returned to brushy cover when frightened or during daylight hours. All sightings of deer on this area also indicate the animals seldom ventured more than 400 yards from the brush perimeter. Brushy basal sprouts of mesquite and other browse species on the sprayed-chained-resprayed upland appeared to offer adequate cover for deer. Deer observed on this treatment usually remained on the area but utilized available cover for concealment.

Results of this study strengthen the suggestions for planned brush control programs. Designs that show patchwork arrangements centering around such natural travel ways as ravines, creeks, and gulleys appear most beneficial. These patchwork arrangements increase the amount of "edge" and interspersion of the welfare factors for wildlife.

Since hunting is of prime importance, the design of brush control patterns can also be employed to enhance hunter success and the "total outdoor experience."

Horejsi, R. G. and D. A. Quinton. 1973. White-tailed deer diets on brush controlled areas, p. 28. In, H. A. Wright and R. E. Sosebee (ed.), Noxious Brush and Weed Control Research Highlights. Vol. 4. Texas Tech University, Lubbock. (Grad. Asst. and Asst. Prof., Dep. Range and Wildlife Manage., Texas Tech University; research conducted near Stamford, Texas).

A study relating deer diets to various brush control treatments was conducted on the Crooked River and Headquarters Ranches in Haskell and Throckmorton counties in north-central Texas.

Horejsi and Quinton 1973 (con't.)

Results suggest that the diets of white-tailed deer on the study area are transitional between the predominately browse diet of northern deer. On untreated and brush control study areas where browse was retained, browse accounted for slightly more than 50% of the yearly volume of white-tailed deer diets. Herbs (1%) and forbs (45 + %) made up the balance of the diet.

Analyses of the data from study areas of moderate to complete brush eradication indicate that white-tailed deer are able to cope with limited habitat manipulation. If suitable habitat is available they alter their food habits sufficiently to maintain themselves in a normal manner. In areas where little browse was available, prickly pear constituted 64% of the yearly diet.

This study also suggest that extensive brush removal will eliminate deer from an area while selective control can maintain or enhance wildlife populations. Deer utilized only the perimeters of extensive areas where brush had been eradicated and were never observed on these areas during daylight hours.

Darr, G. W. and D. A. Klebenow. 1975. Deer, brush control, and livestock on the Texas Rolling Plains. J. Range Manage. 28:115-119. (Grad. Asst. and Asst. Prof., Dep. Range and Wildlife Manage., Texas Tech University, Lubbock; research conducted near Colorado City, Texas).

White-tailed deer (*Odocoileus virginianus*) were observed by spotlight in the Rolling Plains of Texas to determine deer use of habitats and how deer were influenced by brush control practices and grazing by livestock. Deer densities were greatest in the bottomland habitat. The sand shinnery oak habitat, the mesquite-juniper redland habitat, and the sandyland ecotone habitat supported moderate densities of deer. Influence of deer use from brush control practices varied in each habitat. Chaining bottomland habitat was detrimental to deer: the larger the area chained, the lower density of deer it contained. Herbicides had little detrimental effect and in some situations may have been beneficial. Grazing by sheep was negatively related to deer densities except in the bottomland habitat. In mesquite-juniper redlands and mimosa-erioneuron uplands, replacing sheep with cattle should increase deer populations.

Beasom, S. L. and C. J. Scifres. 1977. Population reactions of selected game species to aerial herbicide applications in south Texas. J. Range Manage. 30:138-142. (Asst. Prof., Dep. Wildlife and Fisheries Sciences, and Prof., Dep. Range Science, Texas A&M University, College Station; research conducted near Raymondville, Texas).

Aerial spraying 80% of a mature honey mesquite brushland in alternating strips with 2,4,5-T + picloram (1:1) at 1.12 kg/ha did not adversely affect populations of white-tailed deer, nilgai antelope, wild turkeys, or feral hogs. Complete treatment (100% sprayed) apparently exceeded the threshold of suitability for all game species surveyed except nilgai antelope. White-tailed deer densities were inversely correlated with production and species diversity of forb populations following aerial spraying. With restoration of the forbs at 27 months after treatment, there were no differences among treatments in deer numbers. Javelina populations, apparently as a result of controlling pricklypear, were significantly reduced by both spray treatments. Reductions in javelina densities were apparent at the final census, 27 months after herbicide application.

Leftwich, T. J. 1977. Man's past and present impact on the status and distribution of the Texas pronghorn. Ph.D. Dissertation. Texas Tech University, Lubbock. 132p. (Grad. Asst. Dep. Range and Wildlife Manage., Texas Tech University; research conducted at Texas Tech University).

Fluctuations in abundance and distribution of pronghorn antelope in Texas were documented from the late Pleistocene to 1976. During pristine times pronghorn ranged over at least two-thirds of the state. They did not occur in the eastern coniferous forest and apparently ranged marginally in the Hill Country of the central Edwards Plateau. Pronghorn populations underwent sporadic fluctuations caused by changes in the condition of their range; this was influenced by local weather conditions, particularly in the arid Trans-Pecos Region.

Between 1800 and 1850, populations along the Gulf Coast were displaced by sheep and cattle introduced earlier by Spanish colonists. From 1850 to 1880 antelope abundance and distribution were further reduced in South Texas, primarily because of overgrazing and competition from large numbers of domestic sheep. Settlement in East and Central Texas also reduced the antelope range to some extent during this time period.

Leftwich 1977 (con't.)

The greatest reduction in antelope distribution and abundance occurred from 1880 to 1924. From original pristine population levels of hundreds of thousands of animals, the total number of antelope left in Texas numbered approximately 2,400 animals, located in scattered herds in the western on-third of the state. This drastic reduction in numbers has been attributed to overgrazing by domestic livestock, fencing of the range, indiscriminate hunting with modern firearms, and extensive cultivation of former pronghorn habitat. During this period, die-offs occurred due to the restriction of movement by fencing during periods of drought and severe winters.

In 1903 the hunting season was closed for antelope throughout the state. Between 1925 and 1945 a transplanting program was initiated to restore antelope to suitable areas in their former range, and antelope herds increased to approximately 8,000 in 1945. During this period, however, intensive farming of row crops such as corn, cotton and wheat were accelerated in west Texas. From 1945 to 1976 antelope populations fluctuated locally with weather conditions but appeared stabilized over most of their range.

Currently antelope are restricted to west Texas with small remnant herd occurring in south Texas. The largest herds occur in the Trans-Pecos Region and on the extreme western edge of the Edwards Plateau where suitable habitat exists on large ranches left in native pasture.

Naderman, J. and B. E. Dahl. 1977. Brush control for white-tailed deer habitat improvement, p. 38. In, R. E. Sosebee and H. A. Wright (ed.), Research Highlights, Texas Tech University, Lubbock. Vol. 8. (Grad. Asst. and Prof., Dep. Range and Wildlife Manage., Texas Tech Univ.; research conducted near Sinton, Texas).

Generally brush control on rangelands is for improved livestock production; however, many species of wildlife may also benefit from brush control. On a brush infested ranch in the Texas Coastal Bend we are studying various size openings to find out the relative amount of brush to open area necessary for optimum white-tailed deer habitat.

Areas ranging from 10 to 80 acres in size were mechanically cleared of brush by roller-chopping. These areas transect several different plant communities both in structure and species composition. No attempt has been made to control resprout brush after clearing; as a result some of the cleared areas have considerable regrowth of brush while others, having slightly different soil types and moisture regimes have little regrowth. Islands of live oak and large mesquite trees were left to evaluate their importance for cover and travel lanes.

Naderman and Dahl 1977 (con't.)

Preliminary data of our study indicates that brush is important for thermal cover and escape cover while the open areas provide more food and are used to avoid predators. Also, deer seemed to prefer openings larger than 10 acres, but they do not readily feed more than 150 yards from brush in larger openings.

In summer when air temperatures in the Coastal Bend area of south Texas often exceeds 100 F in direct sunlight the shade produced by the shrub canopy reduces temperatures by 10 F or more. During the winter and early spring months when the air temperature is often below 50 F with a wind chill factor of 30 F or less the brush canopy, through its insulating affects, helps the animal conserve body heat.

Escape cover from human activity is obviously important to a hunted population of deer by providing protection from the hunter's arrow or gun. Those deer that survive are left to reproduce fawn the following year thus there is the possibility of an evolutionary trend, through acquired and learned behavior, for deer to select brush for escape cover from humans. On the other hand, our study indicates that the open areas are important to white-tailed deer by reducing predation from "natural predators" (coyote and bobcat). Deer can better observe the number and movements of predators where they can see over the top of the vegetation or where the brush is open.

Germano, D. J. 1978. Response of selected wildlife to mesquite removal in desert grassland. M.S. Thesis. University of Arizona, Tucson. 60p. (Grad. student, University of Arizona; location of where research was conducted is unknown).

Creating clearings in mesquite is far less detrimental to wildlife than completely clearing whole ranges. In some cases, it benefits wildlife. For the rancher, grass production will increase. For those interested in wildlife, clearings in mesquite will still leave valuable food and cover. "Edge" is greatly increased by irregular shaped clearings. Gambel's quail seemed to have benefited greatly from the increased edge. Populations of cottontail were extremely low, however, if they are studied when the population is at a high, cottontail may show increased use of the clearings. Scaled quail, which seemed to prefer a more open habitat, may increase more rapidly with clearings and mesquite available. Numbers of most selected mammals and birds were lower in the mesquite-free range. Total destruction of mesquite is detrimental to the indicator mammals and birds I studied and may be for many other species.

Zebra-tailed lizards, desert spiny lizards and western whiptails would suffer from the elimination of mesquite, but spot clearing would not severely lower numbers. Tree lizard numbers would increase with clearings as long as dead mesquite was left. The sonora spotted whiptail does well in mesquite with clearings.

Germano 1978 (con't.)

Aesthetically, spot clearing of mesquite may be much more desirable to the public than total clearing of mesquite. This is one aspect of shrub control which should be studied.

Wildlife response to spot clearing should be studied after 5 to 10 years following treatment. The effects I found may be ephemeral and not applicable to wildlife many years after treatment. Mesquite require persistent periodic control to maintain a brush-free range. Range managers will have to weigh the cost versus benefit of keeping ranges open in spots for increased grass production.

The response of wildlife to mesquite removal in desert grassland is favorable for spot clearing and unfavorable for totally removing mesquite. Spot clearing in mesquite gives a greater diversity of habitat, has less visual impact than total clearing of mesquite, is less detrimental to all classes of vertebrates and still accomplishes range management objectives for more grass.

Steuter, A. A. 1978. Response of wildlife to brush control in the Rio Grande Plain. M.S. Thesis. Texas Tech University. Lubbock. 49p. (Grad. Asst., Dep. Range and Wildlife Manage., Texas Tech University; research conducted in Dimmitt and Webb counties of Texas).

Habitats in South Texas were described using brush cover, grass cover, horizontal vegetation density and range site. Six of 12 study areas had received brush control treatments. Treatments included herbicide (Tordon 225), herbicide followed by burning, and a 20-year old rootplowed treatment.

The herbicide treatment resulted in a slight decrease in live brush cover 2 years after spraying. Horizontal vegetation density was unaffected. Grass cover averaged 59% on treated sites and 11% on untreated sites. Mesquite mortality was 35%. Few plants (<10%) of other woody species were killed. Most cacti were killed or greatly reduced.

Spraying and burning decreased live brush cover from 88% to 26% 16 months after treatment. Horizontal vegetation density was one-half that of the control, while total grass cover averaged 91% on treated and 11% on control sites. Mature mesquite trees were reduced 48%, largely due to the herbicide. Of the surviving mature plants 77% maintained living portions of their original canopy after spraying but only 25% maintained original canopy when spraying was followed by burning. The density of young mesquite was about 50% less following burning of sprayed brush, lengthening the effective control period of mesquite.

Steuter 1978 (con't.)

Call counts of bobwhite quail were higher on both the sprayed and sprayed and burned treatments than on untreated areas, during the summer of 1977. Part of this difference may have been due to the natural productivity of the different range sites. A higher call count was again obtained on the sprayed and burned area than on an adjacent control area with the same range site during the summer of 1978.

Coyote activity, as measured by the scent-post technique, was highest on the sprayed and burned treatments. Habitat preference of coyotes was felt to be more closely related to food supply than to structural features of the vegetation.

A positive correlation existed between deer density measured with a helicopter census and deer activity measured from systematic tower observations ($Y = 0.921e^{2.30X}$, $r^2 = 0.95$). Deer densities during the summer, were positively correlated with percent total brush cover on study areas ($Y = 0.522e^{0.028X}$, $r^2 = 0.82$) and study sites ($Y = 0.0000003X^{3.463}$, $r^2 = 0.67$).

Maximum deer use of study sites fell within three cover classes, 0 to 43, 43 to 60, and 60 to 97%. Deer use within a cover class always fell below the maximum level. The interpretation was that to sustain deer numbers at a selected level, a corresponding brush cover was required. Other habitat parameters and management practices would determine whether a site would reach the maximum level of deer use.

Horizontal vegetation density of a site was correlated, to a lesser degree, with deer use. This may imply that although the security provided by brush is important, the number of woody species and their distribution was also important. Deer reliance on browse, along with the present cover and composition data, indicate that brush was important for security and food during the summer in the Rio Grande Plain.

Tanner, G. W., J. M. Inglis, and L. H. Blankenship. 1978. Acute impact of herbicide strip treatment on mixed-brush white-tailed deer habitat on the Northern Rio Grande Plain. J. Range Manage. 31:386-391. (Research Asst. and Prof., Dep. Wildlife and Fisheries Science, Texas A&M University, Texas A&M University, College Station, and Prof., Texas A&M University Research Center, Uvalde, Texas; research conducted in Zavala Co., Texas).

Tanner et al. 1978 (con't.)

White-tailed deer tended to evacuate a 1,800 ha, mixed-brush pasture during 5 months following aerial strip-spraying in May with 2,4,5-T + picloram (1:1) at 0.56 kg/ha and 1.12 kg/ha and in two widths (80% coverage). Deer were attracted to the pasture in above-normal numbers the following winter but their numbers returned to normal by 11 months posttreatment. Apparently, succulent woody plant regrowth provided an attractive food base which induced the posttreatment increase in numbers. Deer on the pasture did not rearrange their use to favor untreated brush as a response to treatment rate or width of treated strip. Woody plant canopy cover was significantly reduced on all treated strips but cover screen at deer height was unaffected. Evidence suggests that only the high rate of herbicide application resulted in significant reduction in the stature of brush. Density of live brush stems was reduced less than 20% by treatment.

II. Effects on Related Resources
C. Wildlife Habitat
1. Antelope and other big game

SUMMARY AND CONCLUSIONS

There is little information pertaining to the effect of spraying mesquite on habitat provided for big game species. However, there are reports in the literature pertaining to mesquite control, primarily by mechanical methods, and its effect on big game habitat.

Tanner et al. (1978) reported that white-tailed deer evacuated a 1800-ha, mixed-brush pasture during 5 months following strip aerial application of 2,4,5-T plus picloram (May). Deer were attracted to the pasture in above-average numbers during the winter following spraying. The authors concluded that succulent, woody plant regrowth provided an attractive food base for the deer.

Apparently, the major effect of mesquite control on big game habitat is related to an "edge effect" resulting from opening up the plant community and improving diet relationships. Naderman and Dahl (1977 and unpublished data) found that size of openings influence deer numbers in south Texas. Openings less than 20 acres in size seem to be too small to attract deer but openings 20 to 80 acres approaches an optimum size. Research in south Texas revealed that prior to brush control, deer populations were significantly depressed (Klebenow et al., 1970), but following brush control to open areas deer numbers began to increase (Naderman and Dahl, unpublished data). The Welder Wildlife Refuge has maintained a relatively constant deer population for several years, but the numbers have declined during the past 2 years following brush control on the neighboring ranch (B. E. Dahl, personal communication).

Presumably, the deer are moving between ranches following clearing.

Germano (1978) found that Desert mule deer and Javelina numbers were not significantly affected by controlling mesquite (Table 7). However, one might assume that the density of mesquite in the southern desert was not as great as portions of Texas. Probably, the community assumed the aspect of a savannah, which would favor big game species.

Several studies report diets of deer as they are related to brush control. Apparently, deer are forced to browse where brush has not been controlled compared to a shift towards a higher percentage of forbs following brush control.

Table 7. Numbers of Desert mule deer and Javelina sighted during visual census of three pastures. (Germano, 1978).

Species	Vegetative Characteristics		
	Mesquite with clearings	Undisturbed mesquite	Mesquite-free
Desert mule deer	27[a][1/]	33[a]	18[a]
Javelina	17[a]	26[a]	0[a]

1/ Values within each species followed by the same letter are not significantly different (P=0.05).

Bell, M. and D. A. Klebenow. 1970. Quail habitat in south Texas, p. 23. In, Noxious Brush and Weed Control Research Highlights. ICASALS Spec. Rep. No. 40. Texas Tech University. Lubbock. (Grad. Asst. and Asst. Prof., Dep. Range and Wildlife Manage., Texas Tech University, Lubbock; research conducted in south Texas).

The type of habitat preferred by bobwhite quail for nesting and brood activities is the objective of this study. Brush infested rangelands are being compared with areas that are natural open grasslands or where considerable brush has been controlled.

The early spring searches indicated a low desnity of birds and widely scattered population. Apparently, early nests and broods were hindered by heavy rains. A dry period in June and July then seemed to delay renesting attempts until late July. The late nests produced numerous broods. The data so far indicate that broods prefer dense herbaceous cover until capable of flight at 3 or 4 weeks. Then less dense or mowed vegetation along roadsides, fence lines, and pipe lines may be used. Areas with dense brush contained few birds. In dense brush habitat, the openings were favored for brooding.

Klebenow, D. A. 1970. Wildlife habitat management by ranchers in Texas, p. 23. In, Noxious Brush and Weed Control Research Highlights. ICASALS Spec. Rep. No. 40. Texas Tech University. Lubbock. (Asst. Prof., Dep. Range and Wildlife Manage., Texas Tech Univ., Lubbock; research conducted throughout Texas).

During the summer, 1970, 8 ranches were visited for wildlife habitat evaluation. All had controlled brush, and all had left areas of cover for wildlife. The treatments varied. Some ranches make hunting game a major part of their management program, and they may leave as much as 50% of their brush untouched. Others may leave less. Some convert their most productive acres to high quality grasslands by brush control and management, including reseeding, but leave the less productive areas for wildlife. Brush on those areas may be controlled in strips. Leaving strips along drainages; leaving blocks of brush; leaving brush in critical areas, such as along river bottoms or watering places; and selectively removing the undesirable species are all techniques that have been tried and are feasible. The amount of brush left usually reflects the importance the landowner places upon wildlife--how many deer, turkey, or quail it takes to satisfy his needs.

Soutiere, E. C. and E. G. Bolen. 1970. Mourning doves and rangeland burns, p. 24. In, Noxious Brush and Weed Control Research Highlights. ICASALS Spec. Rep. No. 40. Texas Tech University. Lubbock. (Grad. Asst. and Assoc. Prof., Dep. Range and Wildlife Manage., Texas Tech University; research conducted near Colorado City, Texas).

Prescribed burning for improved forage production and/or for the control of mesquite on native rangelands imposes a concurrent effect on wildlife habitat. A field study was accordingly initiated in 1970 to determine the effects, if any, that rangeland burning might have on the nesting habitat and reproductive success of mourning doves.

The study area includes sites (a) burned in March, 1969, (b) burned in March, 1970, and (c) an unburned control area. Twenty-three 5-acre plots were regularly searched for dove nests for 5 consecutive months beginning in April, 1970. Nests were found both on the ground and in mesquite trees in each treatment area; a detailed history was compiled for each nest. Plant cover, basal area, density, and other vegetational measurements were made for the grasses, forbs, and woody plants in each 5-acre plot.

Mourning doves nested in each of the sites. In all, 133 active dove nests were located on the plots. More ground nests were found in the 1970 burn than elsewhere, and more tree nests were situated in the unburned control. However, there was no statistical difference in the total number of dove nests (tree nests plus ground nests) between either of the treatments or the control. Likewise, there was no difference in the nest success (i.e. nests which produced squab) between these areas. The study will be expanded in 1971.

Tharp, J. E. 1971. A study of scaled and bobwhite quail with special emphasis on habitat requirements and brush control. M.S. Thesis. Texas Tech University. Lubbock. 58p. (Grad. Asst., Dep. Range and Wildlife Manage., Texas Tech University; research conducted near Colorado City, Texas).

Vegetation and quail data were collected on 14 study areas in seven vegetation types, to determine habitat requirements, and the effects of brush control on bobwhite and scaled quail. The vegetation data were entered into a step-wise multiple regression program as independent variables and the quail populations as dependent variables.

The interaction between these independent variables accounted for most of the variations in scaled and bobwhite populations during breeding, brood raising and coveying.

The effects of brush control will vary with the type of habitat, the amount of preferred canopy cover existing before and after treatment, the amount of grass cover existing before and after treatment, and the species of quail involved. Spraying in bottomland habitats appears to be immediately detrimental to bobwhite quail, but has a minor effect on scaled quail. As grass cover increases on these sites, they should have the potential to carry a higher bobwhite population than the untreated habitats.

Chaining in bottomland habitats was detrimental to both species. Strips of brush and selected shrubs should be left if these areas are to maintain a good quail population.

The deep hardland habitats were of minor importance to scaled quail, but highly preferred by bobwhite. Because of the heavy grass cover normally on these areas, spraying had little effect on either species unless all brush was removed.

In regard to herbicide spraying, I agree with Jackson (1969) who stated that brush control as currently practiced may be resulting in better quail habitat generally by encouraging sprouting of mesquite which results in low cover better suited to quail than tall mesquite trees.

Turrentine, J. M. 1970. The ecology of bobwhite quail in aerially sprayed sand shinnery oak habitat. M.S. Thesis. Texas Tech University. Lubbock. 83p. (Grad. Asst., Dep. Range and Wildlife Manage., Texas Tech University; research conducted in Wheeler and eastern Gray Counties, Texas).

A study of bobwhite quail habitat use was conducted during 1970-1971 on seven areas in Wheeler and eastern Gray Counties in the Texas Panhandle. The major objective was to determine how aerial spraying of sand shinnery oak would effect quail habitat and cover in this vegetation type. Other objectives were to determine how complete brush removal would effect quail and to evaluate spring strip discing as habitat improvement practice.

Vegetation analysis showed spraying reduced canopy cover and shrub height. An area which contained no brush, due to several retreatments, had the highest amount of grass cover during both years of the study. Lack of early spring rains during 1971 caused a 50% reduction in herbaceous and woody canopy cover from that recorded in the previous year.

Spring discing appeared feasable for improving quail habitat, since it increased the forb cover by three to five times. Discing in long strips creates more edge than discing in blocks. Discing half of the strip in alternate years produces two seral stages that provide a more diversified food source. Strips should be located near woody escape cover.

Quail nested ¼ mile into the area containing no brush. They later used this area for feeding, but they remained within 200 yards of woody cover in adjacent pastures and flew to this cover when flushed. The need for escape cover forced these birds to remain within easy flight distance of woody cover.

Drought conditions in early 1971 caused a reduction in brood production from that observed in the previous year.

Sprayed and unsprayed areas had adequate cover to maintain quail populations year-round with the exception of the no brush area which had quail use only along edges near pastures containing brush. Dead stems of spray killed plants provided cover until the oak regrew. This effect could change with use of more effective herbicides or persistent use of present herbicides which remove all woody cover. To insure adequate cover for quail, portions of an area should remain untreated. Brush could be left in strips, the width of the strip to vary with the density of the brush. Distance between brush strips should probably not exceed 400 yards, so that a bird in the center is within flying distance of cover. As many oak mottes and clumps of brush should be included in the strips as possible since they furnish loafing and essential escape cover.

Montei, A. K. 1973. Rio Grande turkey diets in brushlands of north-central Texas. M.S. Thesis. Texas Tech University. Lubbock. 64p. (Grad. Asst., Dep. Range and Wildlife Manage., Texas Tech University; research conducted near Stamford, Texas).

Brush control areas (Hendrick Ranch) produced 38 different turkey sightings involving 175 hens and 176 toms. During the same period turkeys on untreated areas (River Ranch) were observed 54 different times giving a total of 59 hens and 183 toms. Five brood sightings were on brush control areas while untreated areas had only one observed brood. Brush control need not destroy turkey habitat. Good turkey populations can be maintained on properly managed brush control areas.

Fecal analysis of turkey droppings appears to give a good indication to turkey diets. Crop contents and fecal analyses during the different seasons gave similar results for the main food species but often varied in food amounts consumed. As long as limitations of the method are realized, fecal analysis can be a useful management tool.

Brush control practices that do not disturb roost trees, mast trees, or berry forming shrubs can actually increase the variety of food items utilized by the turkey. Areas being controlled should be small so turkeys will enter the area to feed. This study indicates that proper brush control could be a good management practice for increasing turkey food resources.

Following is a discussion on some of the more important food items in the turkeys' diet:

1) Pecan mast was the most important winter food item when production was good. Mast was avialable through most of the winter months in 1972. Brush control measures should not interfere with this tree species, not only because of its food value but also because of their value as roost sites.
2) Ironwood berries provided food for many forms of wildlife during the fall. Berries did not last throughout the winter but when available, they were highly preferred. This shrub should be protected from brush control practices.
3) Tridens retained its seeds well into the winter months and was heavily utilized from middle summer through early winter. This was the most important grass species.
4) Bristle grass and Texas cupgrass were turkey favorites in the early growing season but their seeds did not last long after fall arrived. Other panic grass seeds (*Panicum*
eaten by turkey. Since many of these grasses are good for cattle, they should be seeded in many areas for the benefit of livestock and turkeys.

5) Sumac (polecat bush and little-leaf sumac) berries were good food sources during the spring and early summer. These shrubs should be protected from control measures.
6) Prickly pear tunas were very valuable for food during the summer and fall. Although no one will manage exclusively for this species, allowing some prickly pear to remain in the pastures would help turkey populations.
7) Wild onion was one of the few green forbs present during the winter months. At this time its green leaves became a valuable source of protein and vitamin A. Turkey took advantage of this plant in the late fall and early winter.
8) Elbowbush and mesquite occurred only in small proportions in the turkeys' diets but field observations of other wildlife scat revealed that fruit and beans of these plants were being heavily utilized. Feral hogs and coyotes in particular utilized these plants. Korschgen (1967) pointed out that mesquite seeds were a valuable turkey food in the summer on the King Ranch in south Texas. At only one time did mesquite seeds occur in turkey diets in this study. Turkeys utilized mesquite leaves during the summer and early fall. Mesquite beans may be a valuable emergency food source for turkeys in north-central Texas.
9) Tasajillo was another plant that provided a good food source through the winter. This plant occurred in greatest abundance near the riverbottom. Brush control on the Hendrick Ranch (treated area) had removed much of this shrub. Ranchers do not like this plant, but leaving it in some areas would provide turkeys with additional winter food.
10) Pigeon berry (*Rivina humilis*) never occurred in great amounts in turkey diets, but it was the second most important forb in their diet during the summer on the untreated area. Since its distribution was limited, they apparently preferred this forb to many others. Korschgen (1967) pointed out that pigeon berry had been listed in field notes as a turkey food but that no assessments had been made of their importance in the diet.

Turkeys make use of food items as they become available. In addition turkeys are one of the more hardy birds. Gerstell (1942) found that wild turkeys could endure at least one week of severe weather without food. "Turkeys survived at least 24 days without food or water with temperatures in the 34° to 50° F. range." To find a starving turkey in the wild would be a rare incident in Texas. Bailey and Rinell (1967) say it best when they state that "turkeys are opportunists, eating whatever acceptable items are most available at different seasons." This study only gives more weight to that statement.

Bell, M. W. 1975. Bobwhite quail production and habitat in the Texas Coastal Bend. M.S. Thesis. Texas Tech University. Lubbock. 51p. (Grad. Asst., Dep. Range and Wildlife Manage., Texas Tech University; research conducted in south Texas).

Six habitats were studied in southern Texas in 1970 and 1971 to determine vegetation characteristics, bobwhite quail numbers and production, and the specific habitat used by bobwhites.

Sandy loam soils had the best quail habitat and populations. Sandy areas had a greater number and abundance of important plant species than clay soil. Diverse herbaceous vegetation provided locally abundant and well distributed food species. Birds also used roadsides and other disturbed areas for feeding. Herbaceous vegetation was used for escape and loafing cover in absence of brush cover.

Areas of moderate brush cover usually lacked the number and abundance of food species for good quail populations. Birds were forced to use roadsides, fencelines, and other disturbed areas for feeding. Proper food and cover could be created by selected brush retention and improvements with discing to create better food sources.

The brush habitat with 50% brush cover did not have enough food species and was considered poor quail habitat. Areas of disturbance yielded enough food to sustain a stable population of quail in the study area. Various patterns of brush removal and discing would increase suitability for quail.

The greatest quail populations were in areas of diverse habitat like the Savannah brush area. Numerous and abundant food species were near adequate escape cover. Areas of little herbaceous diversity had the lowest quail numbers. This was typical of the brush controlled area that had no pairs in 1970 and only one in 1971. Populations were generally down in 1971 and several study areas had significant decreases in pairs.

Moist weather in 1970 kept vegetation green throughout the spring and summer providing good nesting conditions. A heavy late May rain may have caused nest desertion or brood mortality, but renesting produced 82% production. Dry conditions in 1971 resulted in only 4% production.

In areas of no brush, distance and tall herbaceous cover was used for escape. In other areas the closest clump of brush was used. Broods and pairs used tall herbaceous cover or spreading mesquite trees for loafing cover.

Bell 1975 (con't.)

This section of Texas often has low densities of bobwhite quail, but has the potential for greater quail numbers. Proper amounts of cover and food are lacking in most areas. Better habitat could be created with selected brush control patterns and by increasing natural food species.

Renwald, J. D. 1975. The use of prescribed fire for bobwhite quail in mesquite-tobosa communities. M.S. Thesis. Texas Tech University. Lubbock. 70p. (Grad. Asst., Dep. Range and Wildlife Manage., Texas Tech University; research conducted near Colorado City, Texas).

This study was undertaken to evaluate the effects of prescribed burning on bobwhite quail populations in the mesquite-tobosagrass community. Investigative efforts were directed at habitat measurements and quail population and diet studies.

Lotebush and mesquite were most important as loafing cover in the winter and summer months. The low-profile and dense canopy of lotebush protected quail from cold winds while mesquite supplied shade during dry summers.

Lotebush furnished the most cover on a year around basis even though mesquite was present in higher densities. A survey of lotebushes typical of the burns revealed most were root sprouts recovering from the effects of the fires. Bushes used by quail were measured with the goal of identifying the minimum size useful to coveys. Understory characteristics of lotebushes used by quail showed a sparseness of vegetation allowed for good visibility by quail.

No vegetational differences were found between roost and non-roost areas. Roost sites differed between winter and summer months with winter roosts found in open grasslands and summer roosts located at the base of lotebushes and mesquite trees.

Home range and headquarter areas were seasonally mapped to follow changes in size and vegetational composition. Summer, 1974 home range data yielded positive correlations between home range size and covey size and between headquarters mesquite density and home range size. These correlations appeared to be related to the dry weather conditions and competition for shade among coveys.

Woody cover measurements revealed a maximum and minimum of total cover acceptable to quail. The smallest amounts were needed in the winter and the greatest amounts were required in the summer.

Renwald 1975 (con't.)

The spring, 1974 nesting season was poor due to lack of precipitation to stimulate pairing. Quail remained in coveys through the summer. The 1975 quail hatch resulted in a reproductive success of 69.0%.

A total of 331 bobwhite quail were captured and released. Capture/recapture figures were similar to those in other studies with an unbalanced sex ratio in favor of males.

The only covey mixing occurred in the spring of 1975 and was limited to several small groups of juvenile birds who usually adopted the nearest covey to their original capture.

Quail densities calculated using the area of occupied range showed that summer, 1974 had the lowest densities and the summer of 1975 had the highest.

Quail weights were used as an index of habitat stability. Summer, 1974 weights showed the greatest differences between coveys due to the hot conditions which influenced daily covey movements. Over time, weights were shown to respond to behavior and environmental influences.

Analysis of fecal samples showed that quail depend on the seeds and leaves of forbs and insects for food. The foods in seasonal diets were not abundant in plant frequency plots so quail must have utilized residual seeds from previous growing seasons.

Prescribed burning for quail habitat should be directed at maintaining the proper amounts and type of woody cover. Firelines should be cleared to preserve lotebushes and clumps of large mesquite during dry years when hot fires are destructive to these plants.

Soutiere, E. C. and E. G. Bolen. 1976. Mourning dove nesting on tobosa grass-mesquite rangeland sprayed with herbicides and burned. J. Range Manage. 29:266-231. (Grad. Research Asst. and Assoc. Prof., Dep. Range and Wildlife Manage., Texas Tech Univ., Lubbock; research conducted near Colorado City, Texas).

A 2-year study of the effects herbicide spraying, and particularly, prescribed burning might have on mourning dove nesting ecology in rangelands infested with mesquite revealed that the loss of trees as nesting sites was compensated by the occurrence of ground nesting. Newly burned areas fostered better utilization (i.e., higher nesting densities) than did older burns except under drought conditions. Ground nests did not suffer from excessive predation, and differences in the productivity of ground nests probably were related to nesting density rather than to the apparent suitability of the site. Ground nests were more successful than tree nests.

Germano, D. J. 1978. Response of selected wildlife to mesquite removal in desert grassland. M.S. Thesis. University of Arizona. Tucson. 60p. (Grad. Student, University of Ariz.; location where research conducted unknown).

Creating clearings in mesquite is far less detrimental to wildlife than completely clearing whole ranges. In some cases, it benefits wildlife. For the rancher, grass production will increase. For those interested in wildlife, clearings in mesquite will still leave valuable food and cover. "Edge" is greatly increased by irregular shaped clearings. Gambel's quail seemed to have benefited greatly from the increased edge. Populations of cottontail were extremely low, however, if they are studied when the population is at a high, cottontail may show increased use of the clearings. Scaled quail, which seemed to prefer a more open habitat, may increase more rapidly with clearings and mesquite available. Number of most selected mammals and birds were lower in the mesquite-free range. Total destruction of mesquite is detrimental to the indicator mammals and birds I studied and may be for many other species.

Zebra-tailed lizards, desert spiny lizards and western whiptails would suffer from the elimination of mesquite, but spot clearing would not severely lower numbers. Tree lizard numbers would increase with clearings as long as dead mesquite was left. The sonora spotted whiptail does well in mesquite with clearings.

Aesthetically, spot clearing of mesquite may be much more desirable to the public than total clearing of mesquite. This is one aspect of shrub control which should be studied.

Wildlife response to spot clearing should be studied after 5 to 10 years following treatment. The effects I found may be ephemeral and not applicable to wildlife many years after treatment. Mesquite requires persistent periodic control to maintain a brush-free range. Range managers will have to weight the cost versus benefit of keeping ranges open in spots for increased grass production.

The response of wildlife to mesquite removal in desert grassland is favorable for spot clearing and unfavorable for totally removing mesquite. Spot clearing in mesquite gives a greater diversity of habitat, less visual impact than total clearing of mesquite, is less detrimental to all classes of vertebrates and still accomplishes range management objectives for more grass.

Steuter, A. A. 1978. Response of wildlife to brush control in the Rio Grande Plain. M.S. Thesis. Texas Tech Univ., Lubbock. 49p. (Grad. Asst., Dep. Range and Wildlife Manage., Texas Tech Univ.; research

Steuter 1978 (con't.)
conducted in Dimmitt and Webb counties of Texas).

Habitats in South Texas were described using brush cover, grass cover, horizontal vegetation density and range site. Six of 12 study areas had received brush control treatments. Treatments included herbicide (Tordon 225), herbicide followed by burning, and a 20-year old rootplowed treatment.

The herbicide treatment resulted in a slight decrease in live brush cover 2 years after spraying. Horizontal vegetation density was unaffected. Grass cover averaged 59% on treated sites and 11% on untreated sites. Mesquite mortality was 35%. Few plants of other woody species were killed. Most cacti were killed or greated reduced.

Spraying and burning decreased live brush cover from 88% to 25% 16 months after treatment. Horizontal vegetation density was one-half that of the control, while total grass cover averaged 91% on treated and 11% on control sites. Mature mesquite trees were reduced 48%, largely due to the herbicide. Of the surviving mature plants 77% maintained living portions of their original canopy after spraying but only 25% maintained original canopy when spraying was followed by burning. The density of young mesquite was about 50% less following burning of sprayed brush, lengthening the effective control period of mesquite.

Call counts of bobwhite quail were higher on both the sprayed and sprayed and burned treatments than on untreated areas, during the summer of 1977. Part of this difference may have been due to the natural productivity of the different range sites. A higher call count was again obtained on the sprayed and burned area than on an adjacent control area with the same range site during the summer of 1978.

Coyote activity, as measured by the scent-post technique, was highest on the sprayed and burned treatments. Habitat preference of coyotes was felt to be more closely related to food supply than to structural features of the vegetation.

A positive correlation existed between deer density measured with a helicopter census and deer activity measured from systematic tower observations ($Y = 0.912e^{2.30X}$, $r^2 = 0.95$). Deer densities during the summer, were positively correlated with percent total brush cover on study areas ($Y = 0.522e^{0.028X}$, $r^2 = 0.82$) and study sites ($Y = 0.0000003X^{3.463}$, $r^2 = 0.67$).

Maximum deer use of study sites fell within three cover classes, 0 to 43, 43 to 60, and 69 to 97%. Deer use within a cover class always fell below the maximum level. The interpretation was that to sustain deer numbers at a selected level, a corresponding brush cover was required. Other habitat parameters and management practices would determine whether a site would reach the maximum level of deer use.

Steuter 1978 (con't.)

Horizontal vegetation density of a site was correlated, to a lesser degree, with deer use. This may imply that although the security provided by brush is important, the number of woody species and their distribution was also important. Deer reliance on browse, along with the present cover and composition data, indicate that brush was important for security and food during the summer in the Rio Grande Plain.

SUMMARY AND CONCLUSIONS

The methods of mesquite control does not influence upland game bird habitat as much as the fact that the habitat has been controlled or manipulated. Steuter (1978) found that call counts of bobwhite quail were more numerous in large pastures where the mesquite had been either sprayed with 2,4,5-T plus picloram or sprayed and burned as compared to no mesquite control. He concluded that at least part of this difference might be attributed to productivity of the different range sites represented in the different treatments. Germano (1978) obtained similar results in Arizona with scaled and Gambel's quail. He sighted more quail in cleared areas than in mesquite infested areas, but the differences were not significantly different (Table 8). The effect on bobwhite habitat apparently is related to amount and kind of cover remaining after mesquite is controlled (Tharp, 1971; Renwald, 1975). It also seems to be related to the availability of food items, e.g. seeds from forbs, etc., following mesquite control (Turrentine, 1970; Bell, 1975).

Germano (1978) sighted many more mourning doves in pastures where mesquite was interspersed with clearings than in either undisturbed mesquite or mesquite free pastures (Table 8). However, spraying mesquite apparently will not detrimentally affect the number of pairs nesting in an area. Dead trees left standing will furnish an adequate nesting site for mourning dove, and if the trees have fallen, the doves will nest on the ground (Soutiere and Bolen, 1970). They also

Table 8. Numbers of birds sighted during the visual census of three pastures. (Germano, 1978).

Species	Vegetative Characteristics: Mesquite with clearings	Undisturbed mesquite	Mesquite-free
Mourning dove	399[a][1/]	59[a]	108[a]
White-winged dove	0[a]	1[a]	1[a]
Scaled quail	36[a]	32[a]	24[a]
Gambel's quail	77[a]	22[a]	1[b]

[1/] Values within the same species followed by the same letter are not significantly different (P=0.05).

found no difference in nest success (i.e. nests which produced squab) between mesquite infested and cleared areas.

Diet components and roosting sites are important in the survival of wild turkeys. Brush control methods that do not disturb roosting sites, mast trees, or berry producing shrubs can actually enhance wild turkey populations (Montei, 1973). Usually wild turkey will not eat mesquite seeds, but they have been reported as a diet constituent. The affect of spraying on associated species would be much more important to consider than spraying mesquite, as long as mesquite or some other trees were left standing to provide a roosting site.

SUMMARY AND CONCLUSIONS

The literature is basically devoid of information pertaining to the effects of spraying mesquite on the habitat for birds of prey.

Ryland, G. 1975. Wildlife thrives in rice land. White River J. Aug. 21. (farmer, southeastern Arkansas).

SUMMARY AND CONCLUSIONS

The literature is largely devoid of any effects from spraying mesquite on habitat of birds other than game birds and birds of prey.

However, Ryland (1975) reported that introduction of rice farming into southeastern Arkansas substantially increased the waterfowl population of that area. The rice fields provided a wetland habitat that had not existed in that area prior to introduction of rice farming. Reservoirs were sampled for TCDD analysis which showed none following use of 2,4,5-T on rice fields.

Germano, D. J. 1978. Response of selected wildlife to mesquite removal in desert grassland. M.S. Thesis. University of Arizona. Tucson. 60p. (Grad. Student; location where research conducted unknown).

Creating clearings in mesquite is far less detrimental to wildlife than completely clearing whole ranges. In some cases, it benefits wildlife. For the rancher, grass production will increase. For those interested in wildlife, clearings in mesquite will still leave valuable food and cover. "Edge" is greatly increased by irregular shaped clearings. Gambel's quail seemed to have benefited greatly from the increased edge. Populations of cottontail were extremely low, however, if they are studied when the population is at a high, cottontail may show increased use of the clearings. Scaled quail, which seemed to prefer a more open habitat, may increase more rapidly with clearings and mesquite available. Numbers of most selected mammals and birds were lower in the mesquite-free range. Total destruction of mesquite is detrimental to the indicator mammals and birds I studied and may be for many other species.

Zebra-tailed lizards, desert spiny lizards and western whiptails would suffer from the elimination of mesquite, but spot clearing would not severely lower numbers. Tree lizard numbers would increase with clearings as long as dead mesquite was left. The sonora spotted whiptail does well in mesquite with clearings.

Aesthetically, spot clearing of mesquite may be much more desirable to the public than total clearing of mesquite. This is one aspect of shrub control which should be studied.

Wildlife response to spot clearing should be studied after 5 to 10 years following treatment. The effects I found may be ephemeral and not applicable to wildlife many years after treatment. Mesquite require persistent periodic control to maintain a brush-free range. Range managers will have to weigh the cost versus benefit of keeping ranges open in spots for increased grass production.

The response of wildlife to mesquite removal in desert grassland is favorable for spot clearing and unfavorable for totally removing mesquite. Spot clearing in mesquite gives a greater diversity of habitat, has less visual impact than total clearing of mesquite, is less detrimental to all cleasses of vertebrates and still accomplishes range management objectives for more grass.

Steuter, A. A. 1978. Response of wildlife to brush control in the Rio Grande Plain. M.S. Thesis. Texas Tech University. Lubbock. 49p. (Grad. Asst., Dep. Range and Wildlife Manage., Texas Tech University; research conducted in Dimmitt and Webb counties of Texas).

Habitats in South Texas were described using brush cover, grass cover, horizontal vegetation density and range sites. Six of 12 study areas had received brush control treatments. Treatments included herbicide (Tordon 225), herbicide followed by burning, and a 20-year old rootplowed treatment.

The herbicide treatment resulted in a slight decrease in live brush cover 2 years after spraying. Horizontal vegetation density was unaffected. Grass cover averaged 59% on treated sites and 11% on untreated sites. Mesquite mortality was 35%. Few plants (<10%) of other woody species were killed. Most cacti were killed or greatly reduced.

Spraying and burning decreased live brush cover from 88% to 25% 16 months after treatment. Horizontal vegetation density was one-half that of the control, while total grass cover averaged 91% on treated and 11% on control sites. Mature mesquite trees were reduced 48%, largely due to the herbicide. Of the surviving mature plants 77% maintained living portions of their original canopy after spraying but only 25% maintained original canopy when spraying was followed by burning. The density of young mesquite was about 50% less following burning of sprayed brush, lengthening the effective control period of mesquite.

Call counts of bobwhite quail were higher on both the sprayed and sprayed and burned treatments than on untreated areas, during the summer of 1977. Part of this difference may have been due to the natural productivity of the different range sites. A higher call count was again obtained on the sprayed and burned area than on an adjacent control area with the same range site during the summer of 1978.

Coyote activity, as measured by the scent-post technique, was highest on the sprayed and burned treatments. Habitat preference of coyotes was felt to be more closely related to food supply than to structural features of the vegetation.

A positive correlation existed between deer density measured with a helicopter census and deer activity measured from systematic tower observations ($Y = 0.912e^{2.30X}$, $r^2 = 0.95$). Deer densities during the summer, were positively correlated with percent total brush cover on study areas ($Y = 0.522e^{0.028X}$, $r^2 = 0.82$) and study sites ($Y = 0.0000003X^{3.463}$, $r^2 = 0.67$).

Steuter 1978 (con't.)

Maximum deer use of study sites fell within three cover classes, 0 to 43, 43 to 60, and 69 to 97%. Deer use within a cover class always fell below the maximum level. The interpretation was that to sustain deer numbers at a selected level, a corresponding brush cover was required. Other habitat parameters and management practices would determine whether a site would reach the maximum level of deer use.

Horizontal vegetation density of a site was correlated, to a lesser degree, with deer use. This may imply that although the security provided by brush is important, the number of woody species and their distribution was also important. Deer reliance on browse, along with the present cover and composition data, indicate that brush was important for security and food during the summer in the Rio Grande Plain.

II. Effects on Related Resources
C. Wildlife Habitat
5. Predators

SUMMARY AND CONCLUSIONS

Almost no research has reported the effect of spraying mesquite on predators. Steuter (1978) found that coyote activity was highest on sprayed (with 2,4,5-T and picloram) and burned pastures. He concluded that habitat preferences of coyotes were more closely associated with availability of food supply than to structural features of the vegetation. Germano (1978) found no differences in coyote sightings in mesquite cleared and mesquite infested pastures. Perhaps mesquite density on his study area was not sufficient to alter the food source of the coyote.

II. Effects on Related Resources
C. Wildlife Habitat
6. Rodents

Guthery, F. S., T. E. Anderson, and V. W. Lehman. 1979. Range rehabilitation enhances cotton rats in south Texas. J. Range Manage. 32:354-356. (Assist. Prof., Dep. Range and Wildlife Manage., Texas Tech University, U.S. Fish and Wildlife Service, and Wildlife Biologist, King Ranch, Inc., Kingsville, Texas; research conducted on the Santa Gertrudis Division, King Ranch, Kleberg County, Texas).

Range rehabilitation in south Texas provided habitat conditions that were suitable for high cotton rat populations in 1961. The mechanisms involved appeared to be an increase in standing crop biomass of herbaceous vegetation and increases in the percentage composition of standing crop by plant taxa that potentially supply food to cotton rats, namely bristlegrasses, sumpweed, and ragweed. Percentage composition of sida, though highly correlated with our density index, likely reflected other habitat features that were truly attractive to cotton rats. Cotton rats achieved the highest densities on rootplowed areas that supported a diverse flora composed principally of lower-successional forbs and grasses.

II. Effects on Rangeland Resources
C. Wildlife Habitat
6. Rodents

SUMMARY AND CONCLUSIONS

The effect of spraying mesquite on rodents has not been reported in the literature. However, Guthery (1979) found that mesquite control by root plowing increased cotton rat density 6 times, primarily as a result of an increase in herbaceous vegetation. Probably one could assume that if diet constituents of rodents is increased, as well as diversified, by spraying mesquite, rodent populations will increase, subsequently, predator populations will increase.

Germano, D. J. 1978. Response of selected wildlife to mesquite removal in desert grassland. M.S. Thesis. University of Arizona, Tucson. 60p. (Grad. student, University of Arizona; location of where research was conducted is unknown).

Creating clearings in mesquite is far less detrimental to wildlife than completely clearing whole ranges. In some cases, it benefits wildlife. For the rancher, grass production will increase. For those interested in wildlife, clearings in mesquite will still leave valuable food and cover. "Edge" is greatly increased by irregular shaped clearings. Gambel's quail seemed to have benefited greatly from the increased edge. Populations of cottontail were extremely low, however, if they are studied when the population is at a high, cottontail may show increased use of the clearings. Scaled quail, which seemed to prefer a more open habitat, may increase more rapidly with clearings and mesquite available. Numbers of most selected mammals and birds were lower in the mesquite-free range. Total destruction of mesquite is detrimental to the indicator mammals and birds I studied and may be for many other species.

Zebra-tailed lizards, desert spiny lizards and western whiptails would suffer from the elimination of mesquite, but spot clearing would not severely lower numbers. Tree lizard numbers would increase with clearings as long as dead mesquite was left. The sonora spotted whiptail does well in mesquite with clearings.

Aesthetically, spot clearing of mesquite may be much more desirable to the public than total clearing of mesquite. This is one aspect of shrub control which should be studied.

Wildlife response to spot clearing should be studied after 5 to 10 years following treatment. The effects I found may be ephermeral and not applicable to wildlife many years after treatment. Mesquite require persistent periodic control to maintain a brush-free range. Range managers will have to weight the cost versus benefit of keeping ranges open in spots for increased grass production.

The response of wildlife to mesquite removal in desert grassland is favorable for spot clearing and unfavorable for totally removing mesquite. Spot clearing in mesquite gives a greater diversity of habitat, has less visual impact than total clearing of mesquite, is less detrimental to all classes of vertebrates and still accomplishes range management objectives for more grass.

SUMMARY AND CONCLUSIONS

Germano (1978) reported the effect of mesquite control (chaining) on reptiles in southern Arizona (Tables 9 and 10). He found that often reptile sightings were dependent upon species. Sometimes a species was more numerous in mesquite free pastures, whereas other species were more numerous in either undisturbed mesquite pastures or mesquite areas with clearings. Probably, the effect is on food supply.

Table 9. Numbers of reptiles sighted during the visual census of the three pastures. (Germano, 1978).

Species	Vegetative Characteristics		
	Mesquite with Clearings	Undisturbed Mesquite	Mesquite-free
Zebra-tailed lizard	20[a] [1/]	61[b]	0[c]
Desert spiny lizard	5[a]	12[a]	0[a]
Lesser earless lizard	31[a]	18[a]	22[a]
Tree lizard	42[a]	16[b]	22[a]
Western whiptail	210[a]	303[a]	3[b]
Sonora spotted whiptail	53[a]	8[b]	70[a]
Unidentified lizards	41[a]	40[a]	55[a]
All reptiles	422[a]	468[a]	187[b]

[1/] Values within the same species followed by the same letter are not significantly different (P=0.05).

Table 10. Numbers of reptiles sighted in the two habitat types of the partially cleared pasture from September 1976 to June 1978. (Germano, 1978).

Species	Vegetative Characteristics	
	Mesquite	Clearings
Zebra-tailed lizard	18[a] [1/]	2[b]
Desert spiny lizard	4[a]	1[a]
Lesser earless lizard	15[a]	16[a]
Tree lizard	9[a]	33[b]
Western whiptail	102[a]	108[a]
Sonora spotted whiptail	34[a]	19[a]

[1/] Values within the same species followed by the same letter are not significantly different (P=0.05).

II. Effects on Related Resources
C. Wildlife Habitat
8. Fish

SUMMARY AND CONCLUSIONS

The literature basically is devoid of information related to the effect of spraying mesquite on fish habitat.

II. Effects on Related Resources

C. Wildlife Habitat

9. Amphibians

The literature basically is devoid of information related to the effect of spraying mesquite on the habitat of amphibians.

Parker, K. W. and S. C. Martin. 1952. The mesquite problem on southern Arizona ranges. U.S. Dep. Agr. Circ. No. 908. 70p. (Range Cons. Southwestern Forest and Range Exp. Sta., USDA-FS, Tucson, Ariz.; research conducted in southern Arizona).

In a study conducted over the period 1940-48 at the Santa Rita Experimental Range, in southern Arizona, the density and yield of perennial grasses on treated range was double that on adjacent untreated range within 3 years after the killing of velvet mesquite. This response took place on a site having average annual precipitation of about 14 inches and bearing such choice forage species as black grama, Arizona cottongrass, and threeawn grasses, and the more abundant but less palatable Rothrock grama. Furthermore, death loss of forage plants from drought was less on the areas where mesquite was killed. The yield of annual grasses under mesquite elimination was over five times that on untreated areas.

Fisher, C. E., C. H. Meadors, R. Behrens, E. D. Robinson, P. T. Marion and H. L. Morton. 1959. Control of mesquite on grazing lands. Texas Agr. Exp. Sta. Bull. No. 935. Texas A&M University. College Station. 24p. (Super. and Technician, Texas Agr. Exp. Sta., Spur, Texas, Plant Physiologist, Crops Research Div., USDA-ARS, Asst. Agron. and Assoc. Animal Husbandman, Texas Agr. Exp. Sta., Spur, Texas; and Research Agron., Crops Research Div., USDA-ARS; research conducted throughout Texas).

Mesquite is an aggressive, deep-rooted undesirable woody, sprouting shrub that occurs on approximately 55 million acres of grazing lands in Texas.

Economical control of mesquite on grazing lands depends largely on the selection of methods that will provide the greatest sustained benefits for the money expanded. Where mesquite thrives, no single method or practice will give effective and economical control under widely varying conditions. Good range and livestock management are essential to obtain maximum benefits from the control of mesquite. The chief value of controlling mesquite is to increase the density, vigor and production of palatable range forage species.

Fisher et al. 1959 (con't.)

Some of the factors that influence the effectiveness and cost of controlling individual plants, in thin, open stands by hand or power grubbing, oiling with kerosene and diesel fuel and basal application of 2,4,5-T and soil application of monuron are discussed in this bulletin.

Factors that influence the effectiveness and cost of controlling moderate to dense stands by chaining and cabling, use of heavy-duty brush cutters, root plowing and aerial application of 2,4,5-T are enumerated.

The benefits of mesquite control include increased carrying capacity of the grazing lands, reduced cost of handling livestock and more efficient use of other range improvement practices.

Reinfestation of grazing lands by mesquite is aided by the dissemination of large numbers of viable seed by cattle, horses, sheep and rodents, the apparent lack of palatability of mesquite foliage to most grazing animals and the failure to maintain a heavy competitive cover of perennial grasses because of overgrazing, drouth and other factors.

The values of mesquite are limited largely to utilization of the beans by grazing animals. Some use also is made of the wood for fuel, fence posts and a source of roughage for feeding livestock. Additional uses include gum, preparation of charcoal and other special products.

Cable, D. R. and F. H. Tschirley. 1961. Responses of native and introduced grasses following aerial spraying of velvet mesquite in southern Arizona. J. Range Manage. 14:155-159. (Range Cons., Rocky Mt. Forest and Range Exp. Sta. and Crops Research Div., USDA-ARS, Tucson, Ariz.; research conducted in southern Arizona).

Herbage production of native perennial grasses and Lehmann lovegrass was compared on sprayed and unsprayed portions of a velvet mesquite-infested pasture.

In 1959, five growing seasons after the final spray treatment, mesquite mortality was 58% on the area sprayed with 3/4 lb of 2,4,5-T in each of the two successive years. On the area sprayed with 3/4 lb followed by ½ lb of 2,4,5-T, mortality was 36%; and on the area sprayed once, 2%. Defoliation in 1959 was 95, 86, and 17%, respectively, on the three treatment areas.

Cable and Tschirley 1961 (con't.)

Herbage production of native perennial grasses averaged almost twice as much on the sprayed as on the unsprayed area for the six growing seasons after the first spraying. Herbage production of lovegrass averaged more than three times as much on the sprayed as on the unsprayed area during the same time. No difference in perennial grass herbage production between the two areas sprayed twice was apparent.

Increased production of perennial grass on the areas sprayed twice more than paid the cost of spraying and seeding in the first three growing seasons after the first spraying. The slow rate of mesquite recovery indicates that the effects of treatment will last several more years.

Martin, S. C. 1963. Grow more grass! By controlling mesquite. Prog. Agr. in Ariz. 15(4):15-16. (Range Cons., Rocky Mtn. Forest and Range Exp. Sta., USDA-FS; research conducted in southern Arizona).

Cable, D. R. and S. C. Martin. 1964. Forage production and stocking rates on southern Arizona ranges can be improved. USDA Rocky Mtn. Forest and Range Exp. Sta. Res. Note RM-30. 11p. (Range Cons., Rocky Mtn. Forest and Range Exp. Sta. USDA-FS, Tucson, Ariz.; research conducted in southern Arizona).

Herbage production of annual and perennial grasses, basal intercept of perennial grasses, and stocking rates have been measured since 1954 on four range units of the Santa Rita Experimental Range, primarily to determine the reaction to mesquite control. Mesquites were killed on two of the units between 1954 and 1957 by spraying diesel oil on the lower trunk of each tree.

The changes in vegetation measured during the 8-year period were caused by three main factors: year-to-year variation in precipitation, management practices, and mesquite control.

The native annual and perennial grasses on these range units are primarily summer growers, and thus depend for their growth primarily on summer rainfall. The correlation between June-September rainfall and perennial grass herbage production is significant, but explains only about 39% of the year-to-year variation in production. Annual grass production, on the other hand, is more closely correlated with rainfall: over half of the year-to-year variation in production is explained by variations in June-September rainfall.

Cable and Martin 1964 (con't.)

Moderate utilization of the perennial grasses combined with alternate-summer deferment of grazing resulted in marked range improvement. On the average, production of perennial grasses increased by more than 4 lb/acre/inch of summer rainfall per year, from about 19 lb/acre/inch of summer rainfall in 1954 to about 45 lb in 1961.

Perennial grass production on the mesquite-killed range units increased relative to the two untreated units between 1957 and 1961. The increase amounted to a net gain of 443 lb/acre on the mesquite-killed units compared to 220 lb/acre on the mesquite-alive units.

Annual grass production was more markedly affected by mesquite density than was perennial grass production. Annual grass production decreased nonlinearly from 20 lb/acre/inch of summer rainfall with 0.25% mesquite crown intercept to 5 lbs with 7% crown intercept.

Calculations of stocking rates that would have given 40% use of perennial grasses for each unit and year show that the stocking rates on the two mesquite-killed units have increased an average of 169% between 1954 and 1961, compared to an increase of 62% on the two mesquite-alive units.

Workman, D. R., K. R. Tefertiller and C. L. Leinweber. 1965. Profitability of aerial spraying to control mesquite. Texas Agr. Ext. Serv. Misc. Pub. MP-784. Texas A&M Univ., College Station. 12p. (Grad. Asst. and Assoc. Prof., Dep. Agr. Eco. and Soc. and Prof. and Head, Dep. Range Sci., Texas A&M Univ., College Station; research conducted in the Rolling Plains of Texas).

At a grazing rental rate of $3.35/animal unit month, (AUM) and with government cost sharing of 50%, the rates of return from spraying mesquite were 26.75% on the upland site and 15.75% on the bottomland site. The lowest rates of return were from spraying on the bottomland site without cost sharing. Returns from spraying on the bottomland site were negative, except at above average rental rates for grazing. The rate of return from spraying was not influenced greatly on either site when the effective life of the spraying practice was reduced by 4 years. This was due to low grazing rates and the long period of waiting for returns from grazing after spraying. However, the rate of return from spraying mesquite on the bottomland site was increased sharply by assuming a 10% deterioration in grazing productivity of the untreated rangeland.

Martin, S. C. 1966. The Santa Rita Experimental Range. USDA, Rocky Mtn. Forest and Range Exp. Sta. Res. Paper RM-22. 24p. (Prin. Range Scientist, Rocky Mtn. Forest and Range Exp. Sta., USDA-FS; research conducted in southern Arizona).

Research was begun in 1903 on the Santa Rita, south of Tucson, Arizona, to learn how to attain maximum sustained forage and beef production on semidesert range with reasonable costs. Results reported cover forage production, including dependence on perennial grasses, grazing management, and methods and advantages of controlling mesquite and other undesirable plants.

Gillette, J. 1967. Brush: the water thief. Supplement to the San Angelo Standard-Times. San Angelo, Texas. 23p. (Science editor, The Standard-Times (San Angelo, Texas; newspaper supplement).

Rechethin, C. A. and H. N. Smith. 1967. Effect on water yield and supply. In, Grassland Restoration Part V. USDA-Soil Conservation Service. Temple, Texas. 46p. (Soil Conserv. and State Conserv. USDA-SCS, Temple, Texas, research conducted throughout Texas).

Robison, E. D., B. T. Cross, and P. T. Marion. 1970. Beef and forage production following honey mesquite control in the Texas Rolling Plains PR 2803, p. 15. In, Brush Research in Texas, 1970, Texas Agr. Exp. Sta. Cons. PR 2801-2828. Texas A&M University. College Station. (Research Assoc., Tech., Super., Texas A&M University, Agr. Res. Sta., Spur, Texas; research conducted at Spur, Texas).

Four cleared and four honey mesquite infested pastures were grazed with mother cows from 1961 through 1968. Although they weighed less initially, cows on cleared pastures maintained heavier weights than those on honey mesquite pastures over the 8-year study period. Calf weaning weights on cleared pastures averaged 510 lb compared with 477 lb for

Robison et al. 1970 (con't.)

calves produced on adjacent native mesquite areas. Improved beef production was valued at $6.28 per acre for 78 cents/acre/year return over the 8-year study when cost of clearing was not considered.

Forage production increased from 1,309 lb/acre on the honey mesquite areas to 1,730 lb on the cleared pastures. Major production increases occurred with a shift from predominantly buffalograss to sideoats grama, silver bluestem and other higher producing grasses.

Fisher, C. E., H. T. Wiedemann, J. P. Walter, C. H. Meadors, J. H. Brock and B. T. Cross. 1972. Brush Control Research on Rangeland. Texas Agr. Ext. Ser. Misc. Publ. MP-1043. Texas A&M Univ., College Station. 18p. (Prof., Asst. Profs., Research Assocs., and Tech., Texas Agr. Exp. Sta., Texas A&M Univ., Agr. Research and Ext. Center at Lubbock; research conducted throughout Texas).

At 20 ranch locations in West, Central and South Texas, 1:1 combinations of 2,4,5-T and picloram consistently gave higher root kills of mesquite and other brush species than 2,4,5-T or a combination of 2,4,5-T and dicamba at the same rates.

The combination of ½ lb of 2,4,5-T and picloram/acre killed an average of 47% of the mesquite compared to 30% for equivalent rates of 2,4,5-T. The greatest advantage of the combination of 2,4,5-T and picloram was the additional control of tasajillo, pricklypear, blackbrush, twisted acacia, granjeno, guajillo and other species that are less susceptible to 2,4,5-T used alone. Higher rates of the combination, 1 lb/acre, did not materially increase the kill of mesquite but did increase the kill of other species such as blackbrush, twisted acacia, granjeno and pricklypear. Whitebrush and lotebush were defoliated, but at the rates and dates of application used, root kills obtained were erratic and rather low. Guayacan or deerbrush and wolfberry were not affected by any of the herbicide treatments.

The highest kills of mesquite were obtained when the rainfall 3 to 6 months prior to application of herbicides was adequate to sustain normal growth and development of foliage. The average maximum air temperature for a 10-day period prior to application of herbicide did not appear to affect plant kills where the development of foliage and soil moisture conditions were favorable.

Fisher et al. 1972 (con't.)

The most effective kills of mesquite and associated species of brush were on sandy upland sites and the poorest kills on bottomland sites, especially where the plants were growing on heavy clay soils. The highest kills of mesquite were on single-stemmed to few-stemmed plants 2 to 4 ft tall. Large, old mesquite trees and dense stands of small many-stemmed regrowth following chaining or other treatment usually showed the lowest percentage plant kills.

Root plowing was the most effective mechanical method tried for controlling mesquite and associated species. A thin "finless" root plow for control of brush with minimum disturbance of desirable grasses appears promising. Power grubbing was effective and economical for control of thin, open stands of mesquite and reinfestation by mesquite and other brush species following other brush control measures. Chaining in combination with aerial spraying offers low-cost control of mesquite. It also reduces the cost of clearing land of heavy stands of large trees prior to root plowing and offers promise of low-cost coverage by aerial seeding of root-plowed land. Use of the railroad chain for control of shin oak, tarbush, creosotebush, and other brush species in combination with goating, aerial spraying and reseeding shows some promise for low-cost control of brush.

Broadcast seeding in combination with roller chopping or use of a cultipacker consistently gave successful stands of grasses. Aerial seeding followed by chaining gave acceptable stands.

Low volume sprays in combination with special diluents may add to the safety and economy of aerial spray applications. Preliminary results show low volume application to be a promising tool for the control of brush and weeds for rangeland improvement.

In grazing studies, calf weights increased an average of 23 lb/head more in aerial-sprayed pastures than in untreated pastures. Grass yields on treated pastures increased approximately twofold over those on untreated. Results of these grazing trials must be considered tentative until further data are obtained for 5 years or longer.

Excellent control of bigelow shin oak in Menard was obtained in 1970 by a combination of shredding, goating and aerial application of ½ lb 2,4,5-T/acre.

Martin, S. C., J. L. Thamus, and E. B. Fish. 1974. Changes in cactus numbers and herbage production after chaining and mesquite control. Prog. Agr. in Arizona 26(6):3-6. (Princ. Range Scientist, USDA-FS, Tucson, Ariz., Prof. Watershed Manage., Univ. Tucson, Tucson, and Asst. Prof. Dep. Park Admin. Texas Tech Univ., Lubbock; location where research

Martin et al. 1974 (con't.)
conducted unknown).

Cable, D. R. and S. C. Martin. 1975. Vegetation responses to grazing, rainfall, site condition, and mesquite control on semidesert range. USDA, Rocky Mtn. Forest and Range Exp. Sta. Res. Paper RM-149. 24p. (Prin. Range Scientists, Rocky Mtn. Forest and Range Exp. Sta., USDA-FS; research conducted in southern Arizona).

Management of Southwestern rangelands must serve various purposes, among which are the raising of livestock, the production of wildlife, provision of open-space recreation opportunities for city dwellers, and the protection of the soil. These uses of rangelands all require (1) the maintenance of a vegetation cover on the land, (2) an understanding of the particular types of vegetation best adapted to particular uses, and (3) an understanding of the effects of particular uses on the vegetation.

Fisher, C. E. 1975. Cooperative brush control research on rangeland, p.20. In, Univ. Texas Coop. Field Day and Tour. 45p. (Prof., Texas Agr. Exp. Sta., Lubbock; research conducted throughout Texas).

Grazing trials on pastures that were aerially sprayed with 2,4,5-T and on those left untreated show that control of mesquite increased calf gain 34 lb/head and reduced the labor required in handling and gathering cattle by as much as 50% at seven ranch locations. They average calf gain per acre was increased 2.6 lb or approximately 16% by the control of mesquite.

Hoffman, G. O. 1975. Mesquite control. Texas Agr. Ext. Ser. Misc. Publ. MP-386. Texas A&M Univ., College Station. 10p. (Ext. Range Brush and Weed Control Spec., Texas A&M Univ., College Station; research conducted throughout Texas).

Mesquite robs 56 million acres of Texas rangelands of precious moisture and plant nutrients each year. It invades an area readily when the soil is bare of high-producing, deep-rooted perennial grasses. Often it is necessary to control mesquite for the ranch to maintain highest

Hoffman 1975 (con't.)

production. The ranchman seeks the most economical control of mesquite with highest livestock production, at the same time conserving natural range resources. He can select from a variety of chemical and mechanical methods or a combination to solve his individual problem. It is not economically possible to eradicate mesquite in a short time. The objective of mesquite control should be improvement of range conditions resulting in a more stable ranching enterprise.

Cable, D. R. 1976. Twenty years of changes in grass production following mesquite control and reseeding. J. Range Manage. 29:286-289. (Prin. Range Scientist, Rocky Mtn. Forest and Range Exp. Sta., USDA-FS, Tucson, Arizona; research conducted in southern Arizona).

Production of native perennial grasses and seeded Lehmann lovegrass was measured periodically for 21 years on a semidesert area where velvet mesquite was controlled by 2,4,5-T aerial spray and on an adjacent unsprayed area to determine how mesquite control would affect grass production and how long the effect would last. Grass production on the sprayed area increased dramatically during the first 5 years in a time-dependent relationship in response to the higher levels of available soil moisture. During the last 12 years, changes in lovegrass production were associated with changes in summer rainfall of the current and previous summers and of the intervening winter (2 separate variables). Because of the strong competition from lovegrass, native grass production during the last 12 years did not show its usual relationship with summer rainfall, but decreased gradually and consistently on both the sprayed and unsprayed areas. At the end of the study period, native grasses provided only 10% of the total perennial grass production on the sprayed area and 20% on the unsprayed. Increased grass production, resulting from the mesquite control treatment and seeding, paid for the treatment within 4 years, and the sprayed area was still producing more grass than the unsprayed area 20 years later.

Cross, B. T., C. E. Fisher, C. H. Meadors, J. H. Brock. 1976. Calf and lamb production following chemical control of honey mesquite. Texas Agr. Exp. Sta. Prog. Rep. PR-3424. Texas A&M Univ., College Station. 2p. (Tech., Prof., and Research Assocs., Texas Agr. Exp. Sta., Chillicothe-Vernon, Lubbock and Chillicothe-Vernon; research conducted in the Rolling Plains, Trans Pecos and Edwards Plateau of Texas).

Cross et al. 1976 (con't.)

Grazing trials were conducted at three ranch locations--in the Rolling Plains, in the Trans-Pecos, and in the Edwards Plateau--from 1969 to 1974 to determine the influence of mesquite control with 2,4,5-T on the weaning weight of calves and lambs.

Pastures of approximately the same size with similar infestations of honey mesquite, soils, and range conditions were selected for each study location. The ranches were located in the Rolling Plains, the Trans-Pecos, and the Edwards Plateau resource areas. Information on major soil types, principal grasses and range conditions for each location was provided by Soil Conservation Service personnel.

One pasture at each location was aerially sprayed with herbicide in early spring. A low volatile ester of 2,4,5-T was applied in June at 0.5 lb/acre in a total volume of 4 gal/acre of 1:3 diesel oil-water emulsion. The comparable pasture was left untreated. Grazing was deferred until fall on both treated and untreated pastures at each location.

The pastures were stocked with brood cows selected by the ranch operator. The initial stocking rate was based on previous experience of the ranch operator and on advice of members of the SCS and the Texas Agricultural Experiment Station. Stocking rates were adjusted each fall to obtain uniform utilization of the available range forage. The percentage of mesquite plants killed was determined from data collected on belt transects 3 years after pastures were sprayed.

Calves were weighed by ranch operators at weaning time in the fall. The calf weights were adjusted for sex at an average age of 9 months.

The average weaning weight of calves raised on the sprayed pastures was 541 lb (318 calves), while the average weight of calves weaned from the untreated pastures was 518 lb (311 calves).

In a grazing study from 1969 to 1973 at Matador, calves weaned from the sprayed pasture averaged 25 lb/head more than calves from the untreated pasture. The average number of pounds gained on the treated pasture was 3.6 lb/acre (or 2,304 lb/section) more than the untreated pasture. From 1969 to 1973, the average stocking rate for the sprayed pasture was 26.4 cows/section, while the untreated pasture carried an average of 23.3 cows/section.

At Monahans from 1970 to 1974, the average weaning weight was 32 lb greater per calf from the sprayed pasture. However, there was little difference in beef gains per acre between the two pastures. The pasture sprayed with 2,4,5-T was stocked at the rate of 9.1 cows/section compared with 9.8 for the untreated pasture. The highest annual average calf weights were 623 and 616 lb for the sprayed and untreated pasture, respectively, in 1974 when the rainfall was 8.15 inches above normal.

Cross et al. 1976 (con't.)

The Menard grazing study was conducted from 1971 to 1973, with a combination of cattle and sheep grazing the sprayed and untreated pastures. The average calf weight on the treated pasture was only 4 lb /head more than on the untreated pastures. The weight gained per acre was 2.1 lb greater for the aerially sprayed pasture because a higher rate of stocking was used. The weight of lambs was essentially the same for both pastures for the 3-year period. Higher average gain for the lambs on the aerially sprayed pasture is thought to be due to the somewhat higher rate of stocking.

Cable, D. R. 1977. Seasonal use of soil water by mature velvet mesquite. J. Range Manage. 30:4-11. (Prin. Range Scientist, Rocky Mtn. Forest and Range Exp. Sta., USDA-FS, Tucson, Arizona; research conducted in southern Arizona).

Mesquites used water consistently to a depth of 3m and outward to beyond the crowns, but use at 15 m was limited mainly to drier periods when water supplies closer to the trees were depleted. With the start of spring growth, water was extracted most rapidly from the surface layers. As the season advanced, the water-supply zone became increasingly thicker. Rates of extraction were highest immediately after recharge in early spring and early summer, and lowest in late fall. Differences in available water in the soil accounted for 72 to 88% of the variation in rates of extraction. The competitive effect of velvet mesquite on perennial grasses is most severe in the upper 37.5 cm of soil under and near the mesquite crowns, and gradually decreases with distance into adjacent openings. The competitive effect in the openings is much more severe in dry years than in wet years.

Scifres, C. J., G. P. Durham, and J. L. Mutz. 1977. Range forage production and consumption following aerial spraying of mixed brush. Weed Sci. 25:48-54. (Prof., Research Asst., and Research Assoc., Texas Agr. Exp. Sta., Dep. Range Science, Texas A&M University, College Station, Texas; location where research conducted unknown).

Production of native grasses following aerial application of 1.12 kg/ha of 2,4,5-T, 2,4,5-T + dicamba, or 2,4,5-T + picloram to a south Texas mixed-brush (*Prosopis-Acacia*) community was significantly increased by all herbicide treatments the year of application, by the herbicide combinations during the second year, but only by 2,4,5-T + picloram

Scifres et al. 1977 (con't.)

the third year after treatment. Moisture-use efficiency based on kg/ha native grass produced/cm precipitation was greatest where the herbicide combinations were applied. Defoliation of woody plants in years of above-average rainfall resulted in favorable grass production responses regardless of herbicide(s). However, range improvement over the 3 years of study was dependent on maintenance of herbicide effectiveness, especially control of underbrush which resulted only where 2,4,5-T + picloram were applied. Consumption of native grass was a direct function of availability in response to brush control as augmented by rainfall. Forb production was reduced by all herbicides the year of treatment and by 2,4,5-T + picloram the year following application, but was not reduced by any treatment during the third growing season.

Dahl, B. E., R. E. Sosebee, J. P. Goen, and C. S. Brumley. 1978. Will mesquite control with 2,4,5-T enhance grass production? J. Range Manage. 31:129-131. (Prof., Assoc. Prof., and Research Assocs., Dep. Range and Wildlife Manage., Texas Tech University, Lubbock; research conducted in the Rolling Plains of Texas).

Both honey mesquite density and percent of plants dead the year of aerial spraying with 2,4,5-T proved to be major factors influencing perennial grass production. Sites with sparse honey mesquite stands and very dense stands (over 50% canopy cover) yielded little extra grass after 2,4,5-T application. Heavy mesquite foliage probably prevented adequate leaf coverage with 2,4,5-T in dense stands, and in sparse stands mesquite competed little with the herbaceous plants. Increased perennial grass production of about 540 lb/acre/year would be necessary over a 5-year period to break even with a $4.60/acre aerial application of 2,4,5-T. With honey mesquite cover of 30%, a plant kill over 80% the year of application was required to provide a 540 lb/acre/year grass increase. However, a 90% kill would provide nearly 750 lb/acre/year extra perennial grass. Thus, paying particular attention to optimum environmental factors and proper timing for the 2,4,5-T application can pay big dividends.

Freeman, B. G., G. T. Richardson, Jr., B. E. Dahl and E. B. Herndon. 1978. An economic analysis of mesquite spraying in the Rolling Plains of Texas. College of Ag. Sci. Pub. No. T-1-177. Texas Tech Univ., Lubbock. 41p. (Asst. Prof. and former Research Asst., Dep. of Ag. Eco., and

Freeman et al. 1978 (con't.)
Prof. and Research Assoc., Dep. Range and Wildlife Manage., Texas Tech Univ., Lubbock; research conducted in the Rolling Plains of Texas).

Linear programming was used to determine the economic feasibility of including brush control by spraying as a long-term investment on the study ranch under the conditions of various cattle prices and various range forage responses to spraying. The study ranch was restricted to 1,123 acres of cropland and 5,000 acres of native range. Cost return budgets were developed for six forage crop enterprises and three cattle enterprises. Five cattle price levels and three range forage responses were evaluated.

The first situation analyzed the ranch organization plan with cattle prices at the second level. The cattle prices for this situation were $35/hundredweight for 400 lb calves, $33/hundredweight for 650 lb calves, $31/hundredweight for 800 lb calves, and $21/hundredweight for 1,000 lb cull cows. Under these cattle price levels, aerial spraying of mesquite that resulted in either a 21 and 31% range forage response were included in the optimal ranch organization plant. Aerial spraying mesquites associated with a 20% range forage response resulted in a 1.4% increase in total net returns over the 7-year period. A 31% increase in range forage as a result of aerial spraying caused total net returns to increase 3.7%.

The second situation evaluated the optimal ranch organization plan with cattle prices at the third level. The cattle prices for this situation were $40/hundredweight for 400 lb calves, $38/hundredweight for 650 lb calves, $36/hundredweight for 800 lb calves, and $26/hundredweight for 1,000 lb cull cows. In this situation the aerial spraying of mesquite activities that resulted in a 21 or 31% increase in range forage were indluced in the optimal ranch plants. The mesquite aerial spraying activity that caused a 21% range forage response increased total net returns by 2%. Total net returns were increased by 4.4% when mesquite control led to a 31% range forage response.

The third situation evaluated the optimal ranch organization plan with cattle prices at the fourth level. The cattle prices for this situation were $45/hundredweight for 400 lb calves, $43/hundredweight for 650 lb calves, $41/hundredweight for 800 lb calves, and $31/hundredweight for 1,000 lb cull cows. In this situation, the aerial spraying mesquite activities that resulted in 11, 21, or 31% increases in range forage were included in the optimal ranch plan. The aerial spraying activity that resulted in an 11% range forage response caused total net returns to increase by .03% over the base optimal ranch plan. The optimal ranch plan that included the aerial spraying activity that caused a 21% response in range forage caused total net returns to increase by 2.5% over the base plan. The optimal ranch organization plan included a 5% increase in total net returns.

The <u>fourth situation</u> evaluated the influence of mesquite control on the optimal ranch organization plan with cattle prices at the fifth level. The cattle prices for this situation were $50/hundredweight for 400 lb calves, $48/hundredweight for 650 lb calves, $46/hundredweight for 800 lb calves, and $36/hundredweight for 1,000 lb cull cows. In this situation, aerial spraying mesquite activities that resulted in 11, 21 or 31% increases in range forage were included in the optimal ranch organization plans. Total net returns were increased by .4% in the optimal ranch plan that included brush control which resulted in an 11% increase in range forage. The optimal ranch plan that included a 21% range forage response as a result of mesquite control had a 3% increase in total net returns over the base ranch plan. Mesquite control by aerial spraying that resulted in a 31% increase in range forage caused a 5.5% increase in total net returns above the base ranch plan for this situation.

The evaluation of the second objective involved the estimation of the present value of changes in net returns associated with brush control by spraying on the study ranch.

The <u>first situation</u> estimated the net present value of changes in net returns for two range forage responses attributable to brush control with cattle prices at the second level. The net present values of the added net returns from brush control were negative for a 21% range forage response. At a 31% range forage response the net present values were positive.

The <u>second situation</u> estimated the net present value of added net returns attributable to brush control with cattle prices at the third level. At the 21% range forage response the net present values were positive for a 7% rate of return. At a 10% rate of return the net present values were at breakeven levels. At the 31% range forage response the net present values were positive.

The <u>third situation</u> estimated the net present value of added net returns attributable to brush control with cattle prices at the fourth level. At the 11% range forage response the net present values were negative. At the 21 and 31% range forage responses the net present values were positive.

The <u>fourth situation</u> estimated the net present value of added net returns attributable to brush control with cattle prices at the fifth level. At the 11% range forage response all the net present values were negative. At the 21 and 31% range forage responses the net present values were all positive.

This study evaluated only the primary benefit (increased forage production) resulting from herbicidal control of mesquite on ranch income. Some additional research is needed in order to evaluate the effects of mesquite control on calving percentages, weaning weights and labor requirements.

SUMMARY AND CONCLUSIONS

Increases in forage and animal production following mesquite control with herbicides have been consistently reported from research in Arizona and Texas. The Arizona studies have dealt with velvet mesquite (*Prosopis velutina*) and the Texas research has been with honey mesquite (*P. glandulosa*). However, the benefits of mesquite removal were not always positive, so it is incumbent on those planning mesquite control and management programs to take advantage of research conducted for many years in the southwest on both species so that control measures are applied only on those areas and by those method most likely to meet the objectives of the control. Results of mesquite removal on forage production have been more consistently positive in Arizona and research reported from that area will be reported first.

At the Santa Rita Experimental Range with 14 inches of annual precipitation, density and yield of perennial grasses was double that of untreated range within 3 years after killing velvet mesquite on a study conducted from 1940-48 (Table 12). Annual grasses produced over five times that on untreated areas after mesquite elimination (Table 13). Velvet mesquite seriously competed with grass with only 15 plants/acre and researchers in charge concluded that effective control would require that mesquite density be reduced below this 15 plant/acre density (Table 14 and 15). They found the relationship between decreasing ground cover of perennial grasses and increasing mesquite crown cover to be nearly linear. Eliminating 101 mesquite trees/acre provided enough extra forage to produce 2150 lb of beef/mi^2 annually (Table 16 and Fig. 2), (Parker and Martin, 1952).

Table 12. Herbage yield per acre of perennial grasses, 1941-48, under different shrub-control treatments applied in 1940. (Parker and Martin, 1952).

Species and treatment	1941	1942 (drought)	1943	1944	1945	1946	1947 (drought)	1948 (drought)	1941-48 average
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Rothrock grama:									
Untreated	70.9	7.2	11.2	19.4	21.2	67.8	17.0	20.8	33.2
Mesquite killed	150.1	41.9	143.7	337.4	132.1	277.6	62.3	98.8	155.5
Burroweed killed	141.0	5.0	27.3	29.0	14.4	21.8	8.8	7.4	32.2
Both noxious species killed	175.0	26.8	116.3	191.4	90.1	117.4	48.6	38.1	100.8
Black grama:									
Untreated	19.6	10.6	17.4	26.9	18.0	23.1	11.8	14.5	21.4
Mesquite killed	43.5	16.7	32.1	48.0	20.2	51.8	19.8	31.4	33.0
Burroweed killed	88.9	7.6	10.7	13.6	12.9	15.0	1.0	.8	18.8
Both noxious species killed	8.9	2.4	7.1	22.1	6.6	11.8	6.8	5.3	8.9
Arizona cottongrass:									
Untreated	3.5	17.7	7.3	68.1	126.0	139.2	52.1	63.9	59.7
Mesquite killed	6.2	8.3	7.4	62.8	119.0	134.5	52.5	83.3	59.2
Burroweed killed	38.8	3.3	7.4	13.0	100.1	84.5	25.8	21.7	36.9
Both noxious species killed	82.2	14.2	21.9	40.3	134.0	95.8	69.5	54.5	64.4
Perennial threeawns:									
Untreated	15.4	17.3	8.1	54.5	33.6	67.8	6.5	6.9	26.3
Mesquite killed	45.7	11.1	17.5	71.8	32.6	98.5	32.7	50.8	45.1
Burroweed killed	80.8	19.0	20.5	25.3	52.0	46.0	13.0	11.6	35.5
Both noxious species killed	82.6	9.3	16.6	46.5	29.3	44.1	11.3	13.9	31.7
Other perennial grasses:									
Untreated	3.1	1.1	1.0	5.1	4.2	2.1	.6	1.8	2.4
Mesquite killed	26.4	.9	.2	7.9	21.8	.6	4.8	8.7	8.9
Burroweed killed	.1	.1	.1	.1	.2	10.7	1.4	.5	1.7
Both noxious species killed	39.2	5.2	6.0	21.8	27.0	57.9	20.7	11.2	23.6
All perennial grasses:									
Untreated	111.9	53.9	45.0	204.0	233.0	300.0	88.0	107.9	113.0
Mesquite killed	271.9	78.9	200.9	527.9	326.0	563.0	172.1	273.0	301.7
Burroweed killed	319.9	35.0	66.0	81.0	179.9	181.6	50.0	42.0	123.1
Both noxious species killed	387.9	57.9	170.9	325.1	287.0	327.0	156.9	123.0	229.5

Table 13. Total herbage yield per acre of annual grasses, 1941-48, under different shrub-control treatments applied in 1940 for the 8 years following application of shrub control. (Parker and Martin, 1952).

Year	Untreated	Mesquite killed	Burroweed killed [1]	Mesquite and burroweed killed
	Pounds	*Pounds*	*Pounds*	*Pounds*
1941	10	109	35	189
1942	T	7	T	10
1943	17	199	62	279
1944	T	23	2	72
1945	6	90	34	145
1946	124	322	329	650
1947	1	8	5	15
1948	7	53	20	59
Average	20.6	101.4	60.9	177.4

Table 14. Herbage yields of native grasses, 1946-50, following mesquite thinning treatments on four different sites. (Parker and Martin, 1952).

Site designation	Original mesquite stand	Mesquite thinning treatment	Herbage production per acre					
			1946	1947	1948	1949	1950	Average
	No./A.	*No./A.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
A	358	No thinning	124	....	11	32	90	64
		25 left	....	....	54	149	325	176
		16 left	....	....	50	154	296	167
		9 left	....	....	67	166	327	187
		All killed	681	....	100	185	390	340
B	138	No thinning	72	104	46	52	331	121
		25 left	....	249	203	80	637	292
		16 left	....	348	276	386	685	424
		9 left	....	437	400	442	1,407	522
		All killed	416	578	483	343	795	523
C	164	No thinning	19	54	13	6	16	22
		25 left	66	103	99	27	278	115
		16 left	116	188	180	1	200	137
		9 left	214	180	116	3	149	132
		All killed	108	214	175	45	271	163
D	44	No thinning	36	111	81	2	36	33
		25 left	48	88	91	3	7	47
		16 left	88	217	128	33	139	121
		9 left	107	110	155	29	399	160
		All killed	68	63	158	2	55	69

Table 15. Herbage yields of Lehmann's lovegrass following various mesquite thinning treatments on two different sites. (Parker and Martin, 1952).

Site	Original mesquite stand	Mesquite thinning treatment	Herbage yields per acre [1]				
			1946	1948	1949	1950	Average
	Number/A.	*Number/A.*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
A	358	No thinning	26	45	40	33	36
		25 left	....	139	252	293	228
		16 left	....	110	198	543	284
		9 left	....	137	214	650	334
		All killed	558	286	200	1,154	550
B	138	No thinning	8	22	15	15	15
		25 left	....	95	85	80	87
		16 left	....	150	105	180	145
		9 left	....	370	120	174	221
		All killed	55	170	105	312	160

[1] No data collected in 1947.

Table 16. Actual herbage yields converted into grazing capacity per section (640 acres) of range without mesquite control. (Parker and Martin, 1952).

Year	Mesquite killed			Mesquite untreated		
	Grass forage yield		Grazing capacity per section	Grass forage yield	Total[1] forage yield	Grazing capacity per section
	Pounds/-acre	*Tons/-section*	*Animal-years*	*Pounds/-acre*	*Tons/-section*	*Animal-years*
1941	136	43.5	11.9	56	21.4	5.9
1942	40	12.8	3.5	27	12.2	3.3
1943	100	32.0	8.8	22	10.6	2.9
1944	264	84.5	23.1	102	36.2	9.9
1945	163	52.2	14.3	116	40.6	11.1
1946	286	91.5	25.0	150	51.5	14.1
1947	86	27.5	7.5	44	17.6	4.8
1948	136	43.5	11.9	52	20.2	5.5
Average	151	48.3	13.2	72	26.2	7.2

[1] Includes forage from mesquite leaves and beans.

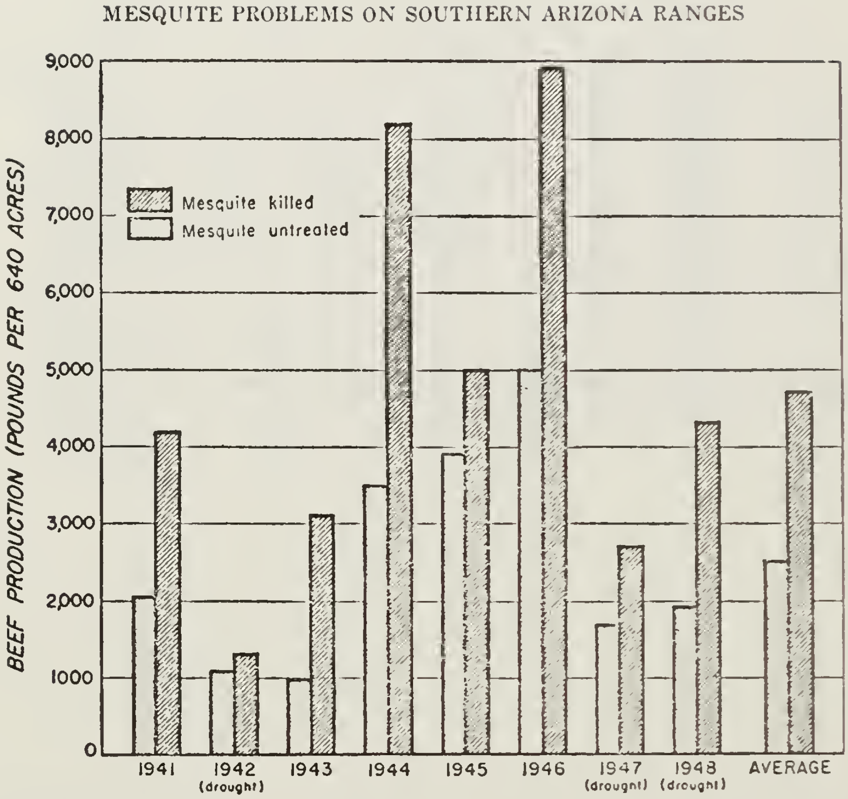


Fig. 2. Estimated production of beef on range with and without mesquite control (Parker and Martin, 1952).

Cable and Martin (1964) found that perennial grass production on the Santa Rita Experimental Range increased over twice as much from 1957 to 1961 (443 vs 220 lb/acre) on velvet mesquite killed units as did that on the mesquite alive range units. However, this substantial increased grass yield was much less dramatic than the similar studies reported from the same area by Parker and Martin (1952). Cable and Martin accounted for the difference in the two studies by indicating that the more recent study was conducted with a more sparse stand of mesquite and a stand of perennial grass at the start of the study. The implication is that forage production is enhanced more by mesquite control if the mesquite stand is relatively dense and the understory vegetation relatively sparse than if a good stand of perennial grass understory occupies the mesquite understory at the time of mesquite control. Work in Texas with honey mesquite control provides a similar conclusion (Dahl et al., 1978). Stocking rates on mesquite-killed units on the Arizona studies increased 169% between 1954 and 1961 compared to a 62% increase on mesquite-alive units. Mesquite were killed by basal application of diesel oil.

On yet another study from the Santa Rita Experimental Range, velvet mesquite was thinned in 1945 to leave 0, 9, 16 and 25 trees/acre compared to an unthinned stand. Similar plots were established at 4 elevations from 3150 to 4100 ft. Killing all mesquite trees increased grass yields several fold at all four acreages. Yields on plots with 16 and 25 trees/acre were about half as great as on those with no mesquite. In 1958, 14 years after treatment, plots without mesquite yielded from 4 to 10 times more grass than unthinned plots. Relative forage increases were greater from mesquite thinning at the lower eleveations, i.e. the drier areas (Tables 17 and 18). But, the increase at these drier sites

Table 17. Lehmann lovegrass. (Martin, 1963).

	4100 ft.	*3700 ft.*	*3400 ft.*	*3150 ft.*
Rainfall (inches)				
Annual - - - - - - - -	17.0	14.0	13.0	12.0
Summer - - - - - - - -	9.8	8.5	7.7	7.9
Mesquite density (trees per acre) - - - -	358	138	164	44
Stocking on adjacent range (acres per cow) - - - -	36	50	80	100

Table 18. Annual and perennial grass. (Martin, 1963).

	4100 ft.	*3700 ft.*	*3400 ft.*	*3150 ft.*
	(Pounds of grass per acre)			
Number of mesquite trees per acre:				
Full stand - - - - - - -	339	172	32	59
25 - - - - - - - - - - -	693	449	211	136
16 - - - - - - - - - - -	898	547	121	316
9 - - - - - - - - - - -	827	966	131	489
None - - - - - - - - - -	1,526	1,078	445	636

was mostly annuals (Martin, 1963). This data vividly shows that although thinning mesquite increases forage, a relatively few mesquite trees (25/acre) still substantially reduces forage yields in the semiarid southwest compared to total eradication.

More recent studies on the Santa Rita Experimental Range provide additional evidence to support the contention that velvet mesquite severely restricts production of herbaceous plants. Martin et al. (1974) compared untreated range to similar range that had been chained in 1970 and to a third area with mesquite controlled by basal oiling with diesel oil. By 1971 mesquite control had not significantly increased yield of annual grasses, but perennial grass production on the mesquite-free tract was more than twice that of the other two areas (Table 19). Bush muhly (*Muhlenbergia porteri*) and the *Sporobolus* sp. increased remarkably on the mesquite-free range.

From this review of selected research conducted on the Santa Rita Experimental Range, the conclusion is that presence of velvet mesquite dramatically reduces grass production and somewhat in proportion to density of the mesquite. Other excellent coverage of these phenomenon is given in Martin (1966) and Cable and Martin (1975) as well as an excellent treatises of the influence of rainfall, site, and grazing management on herbage yield. Nevertheless, these studies do not directly answer the question "What is the role of aerial herbicidal control of velvet mesquite on forage production?" The best indication that aerial mesquite control with 2,4,5-T gives similar grass response to control by other means, e.g. basal oiling with diesel, is provided by Cable and Tschirley (1961) and Cable (1976).

The Arizona researchers aerially sprayed velvet mesquite dominated range (about 225 trees acre) with 2,4,5-T in 1954 and again in 1955.

Table 19. Herbage production (kg/ha) of annual and perennial grasses in 1971 on the chained and untreated areas. (Martin et al., 1974).

	Chained	*Check*	*Mesquite-Killed*
Annual grasses*	186a	118b	112b
Perennial grasses*	235b	187b	476a
Total grasses*	421b	305b	588a

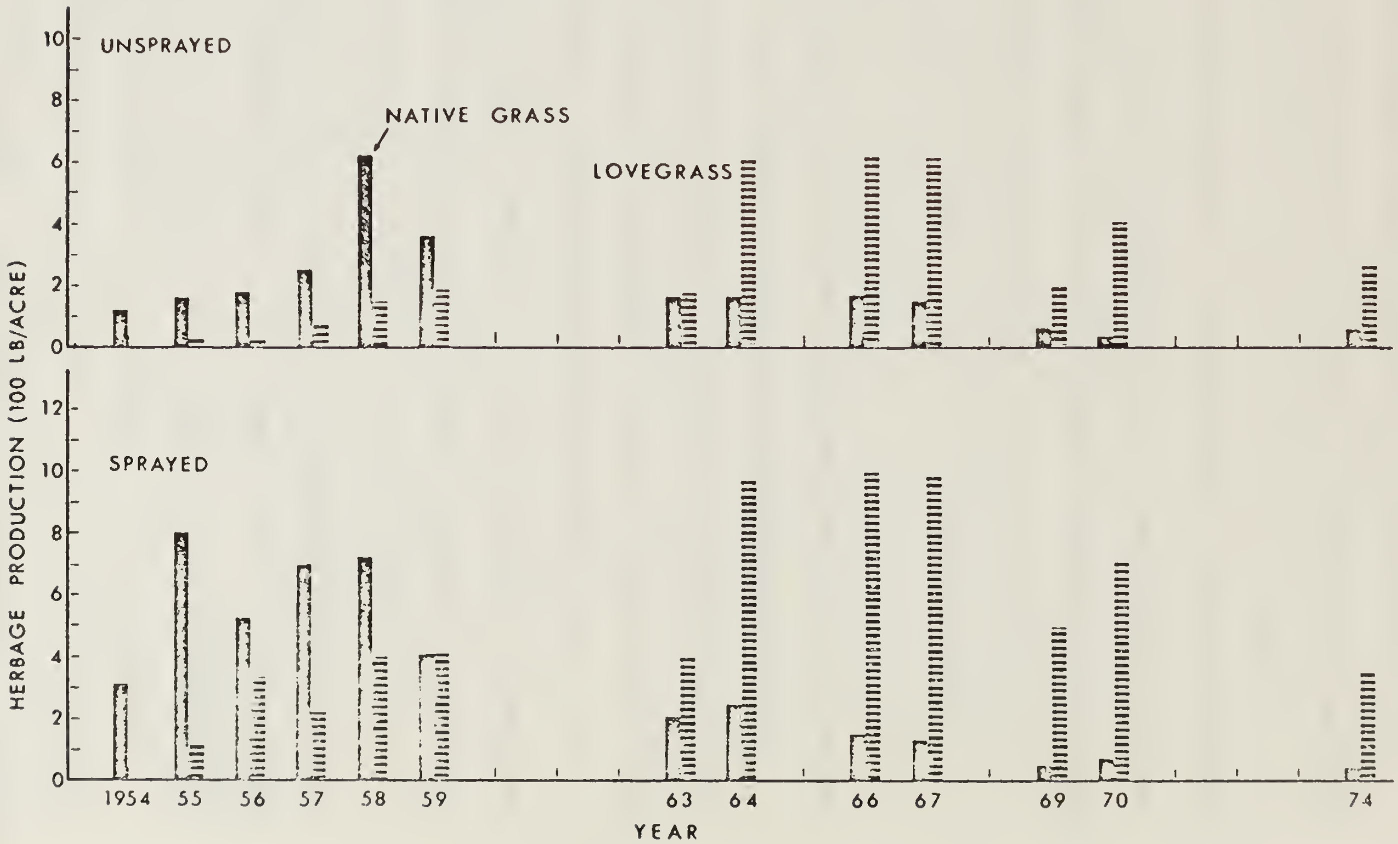
**Difference significant at 5% level*

Also, Lehmann lovegrass (*Eragrostis lehmanniana*) was seeded without seedbed preparation on the 100 acre herbicide treated area and a similar 100 acre untreated area. Grass production increased dramatically on the sprayed area during the first 5 years. Native grass production averaged 611 lb/acre compared to only 267 lb/acre on the unsprayed area. After 20 years, the sprayed area still produced significantly more grass than the unsprayed area. Thus, they concluded that it would be better to control mesquite on a similar undisturbed area than to re-treat this area, even after 20 years. Cattle stocking rate was 10.2 head/section from 1943-1953 before treatment compared to 21 head/section for the study period. However, two factors should be mentioned here--1) the early years of the study were unusually wet; and 2) on treated areas a relatively sparse remnant stand of native grasses quickly reoccupied the site with the favorable conditions so seeding would not have been necessary. Over time, the Lehmann lovegrass out-competed the native grasses to where the natives only comprised 10 to 20% of the grass stand (Fig. 3).

These studies leave few doubts that velvet mesquite severely restricts grass production in that portion of Arizona serviced by the Santa Rita Experimental Range. Also, the studies indicate that broadcast herbicidal control that does not harm understory grasses would provide increased grass production similar to other means of control--of course this would be commensurated with the degree of control obtained.

Work by Cable (1977) on soil water use by velvet mesquite provides probably the best explanation why velvet mesquite is so competitive with grasses. He found that velvet mesquite used water consistently to a depth of 3 m and outward to 10 m beyond the crowns (canopy) but use at 15 m beyond the mesquite canopy was limited mainly to drier periods

Fig. 3. Herbage production of native perennial grasses (solid bar) and Lehmann lovegrass (hatched bar) on sprayed and unsprayed areas. (Cable, 1976).



when water supplies closer to the trees were depleted (Fig. 4). The competitive effect of velvet mesquite on perennial grasses was most severe in the upper 37.5 cm of soil under and near the mesquite crowns (canopy), and gradually decreased with distance into adjacent openings. The competitive effect in the openings was much more severe in dry than in wet years.

As in Arizona, research in Texas to evaluate benefits of mesquite removal to forage and animal production has been conducted since the mid 1940's. Grazing trials with yearling steers were conducted at Spur, Texas during the summers from 1945 to 1954 on 8 pastures four without mesquite control and four cleared of mesquite by removing the tops and treating the stumps. Sprout growth was controlled at 5-year intervals by aerial spraying of 2,4,5-T. During the 10 years steers averaged 204 vs 173 lb of gain for the cleared and uncleared pastures. Summer stocking rates was 6.5 acres/head for an annual grazing period of 156 days (Fisher et al., 1959). Note that they maintained the same stocking rate for both treatments (Table 20 and Fig. 5).

Robison et al. (1970) reported on another facet of the same Spur study conducted from 1960 to 1968 with cows and calves. During 8 years, weaning weight of calves on brush pastures averaged 477 vs 510 lb for calves on mesquite cleared pastures. Greater differences in weaning weights occurred in years when growing season rainfall was limited or poorly distributed. Easier handling of cows and calves was another plus for the cleared pastures. Forage yields obtained in 1968 showed that cleared pastures produced 421 lb/acre more forage than adjacent brush pastures (Fig. 6). Their data also showed that mesquite control was more beneficial to the better forages, i.e. sideoats grama (*Bouteloua curtipendula*) and silver bluestem (*Andropogon saccharoides*) than to increaser species such as buffalograss (*Buchloe dactyloides*) (Fig. 6 and 7).

Fig. 4. Increasing dependence on hole 6 (15 m beyond edge of crown) for water as soil water closer to the trees is depleted (3-period moving average rate of extraction, 100-cm depth. April to December, 1973) (Cable, 1977).

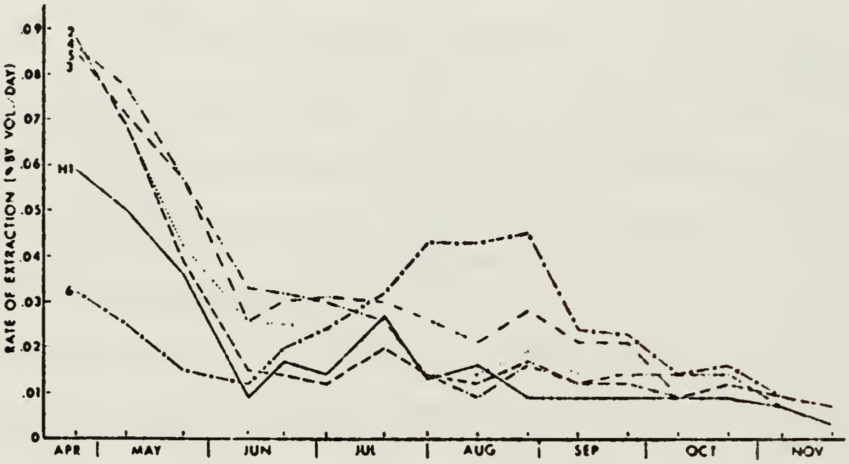


Table 20. Summary of grazing trials with yearling steers during the summer on cleared and mesquite-infested pastures, for the 10-year period, 1945-54 (Fisher et al., 1959).

Treatment	Average number of steers	Acres per head	Number of days grazed per season	Average gain, pounds		
				Steer	Daily	Acre
Cleared, upland	6.0	8.0	154	184	1.19	22.75
Mesquite, upland	6.0	8.0	154	148	.96	17.92
Cleared, bottomland	7.0	5.0	158	224	1.41	44.24
Mesquite, bottomland	7.0	5.0	158	198	1.25	38.40
Average cleared	6.5	6.5	156	204	1.30	33.50
Average mesquite	6.5	6.5	156	173	1.10	28.16

Fig. 5. Influence of mesquite control on steer and acre gain during 1945-56 at Spur on upland and bottomland pastures. Bottomland pastures have produced approximately twice as much beef gain per acre as closely adjoining upland pastures (Fisher et al., 1959).

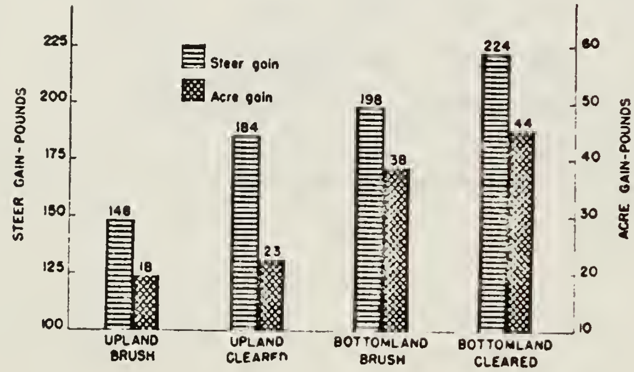


Fig. 6. Total pounds per acre and grazing value of forage produced on cleared and brush-infested pastures, Spur (Robison et al., 1970).

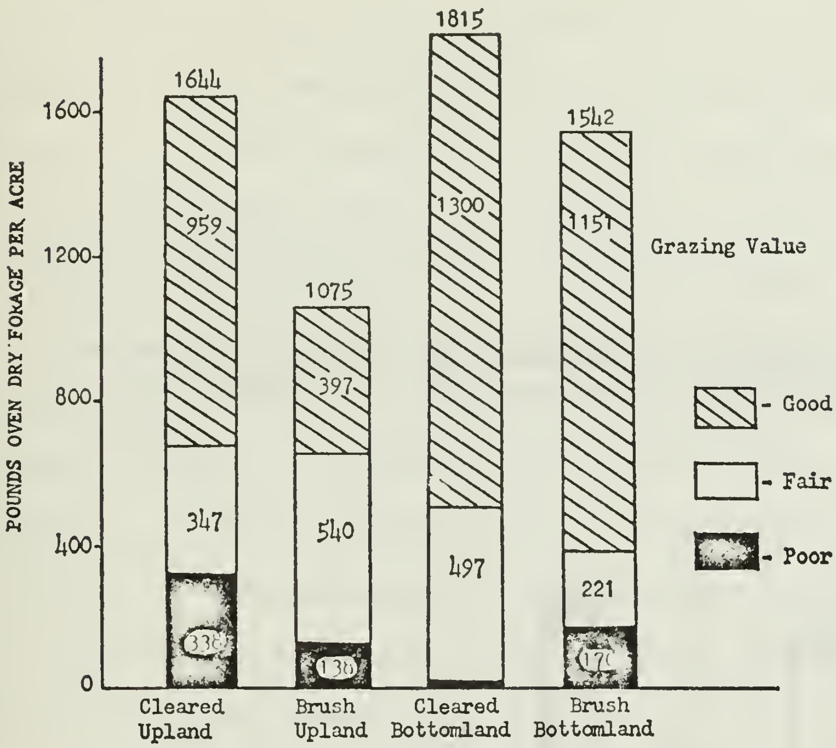
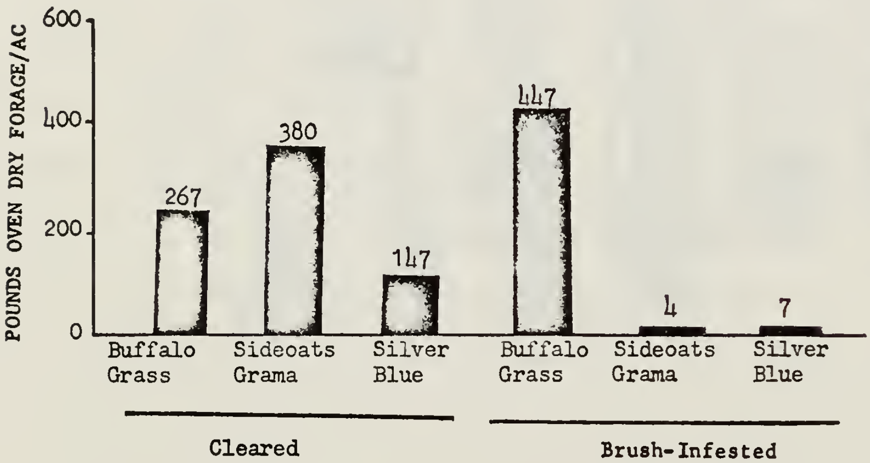


Fig. 7. Forage production (pounds per acre) from selected species growing on cleared and brush pastures, Spur. (Robison et al. 1970).



On pasture-scale studies conducted on 7 ranch locations throughout west Texas, Fisher (1975) reports that calf gain increased 34 lb/head on pastures aerially sprayed with 2,4,5-T and that labor required to gather and handle cattle was reduced 50% on cleared pastures. Cross et al. (1976) reported from 3 of the ranchers from the same study that calves weaned at 541 lb (318 calves) on 2,4,5-T sprayed pastures compared to 518 lb (311 calves) on untreated pastures from 1969 to 1974 (Table 21). Robison et al. (1970) reports forage yields from the Matador Ranch, Matador, Texas (one of the ranches included in the above reported study) in 1968. The average over-dry forage production (sampled in August) on the pasture sprayed with 2,4,5-T 14 months previously, was 1185 vs 1353 lb/acre on the uncleared pasture. As reported for earlier studies, the higher producing forage species responded proportionately better to mesquite removal (Fig. 8 and 9).

Workman et al. (1965) reported from a survey of ranchers in the eastern part of the Texas Rolling Plains, that grazing capacity on upland sites was increased from 22 to 17 acres/AU/year, and from 20 to 16.5 acres/AU/year on bottomland sites following aerial spraying with 2,4,5-T (Table 22). The estimated grazing rate on the upland site peaked at 0.71 AUM's/acre the first year after spraying beginning to decline the fourth year. Grazing rate peaked on bottomland sites at 0.73 AUM's/acre 1 year after grazing and began to decline 3 years after spraying. Results of these interviews gave surprisingly similar results to research reported from the area.

The only Texas study found relating grass yield to mesquite density or canopy cover was conducted by Dahl et al. (1978) from 1970 to 1975 in west Texas. Just as reported by Workman et al. (1965), their data showed peak grass response the year after spraying. However, rather than

Table 21. Summary of grazing trials conducted on pastures aerially sprayed with 2,4,5-T to control honey mesquite and on untreated pastures at three ranch locations from 1969 to 1974 (Fisher, 1975).

Brush treatment	Years	Ranch location	No. of calves	Avg., animal units per section	Avg. Calf weight, lb.	Lb. gain per acre[1/]
Sprayed	5	Matador	138	26.4	552	22.80
None	5	Matador	122	23.3	527	19.18
Sprayed	5	Monahans	86	9.1	598	8.52
None	5	Monahans	85	9.8	566	8.65
Sprayed	3	Menard[2/]	94	21.1	471	15.5
None	3	Menard	104	18.4	467	13.4
Total and average for calves						
Sprayed		3 Locations	318	16.6	541	14.1
None		3 Locations	311	15.9	518	12.8
Total and average for lambs			No. of lambs		Avg. lamb weight, lb.	
Sprayed	3	Menard	375	84.2	79.3	10.2
None	3	Menard	408	72.1	79.2	8.9

1/ Acre gain corrected for differences in pasture size at each location.

2/ At Menard the pastures were also stocked with sheep.

Fig. 8. Total pounds oven-dry forage produced per acre in open areas and under trees on sprayed and untreated honey mesquite pastures on the Matador Ranch, Matador (Robison et al., 1970).

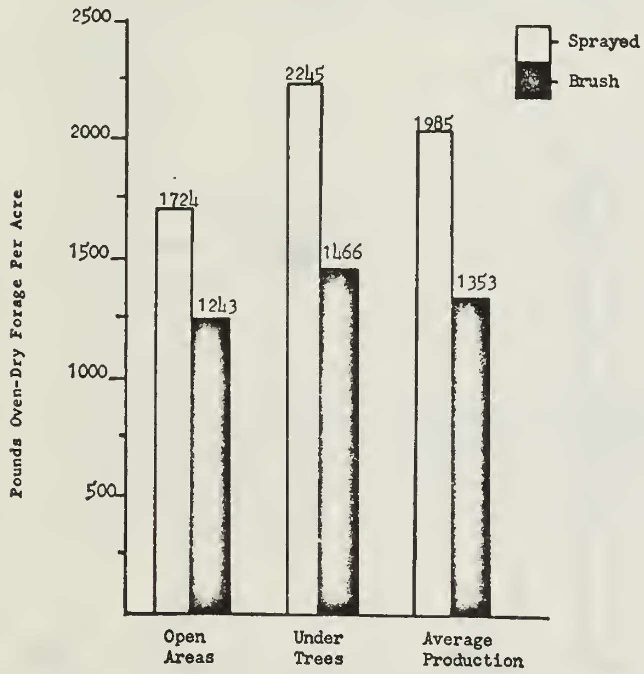


Fig. 9. Total pounds oven-dry forage production per acre of selected species from sprayed and untreated pastures on the Matador Ranch, Matador (Robison et al., 1970).

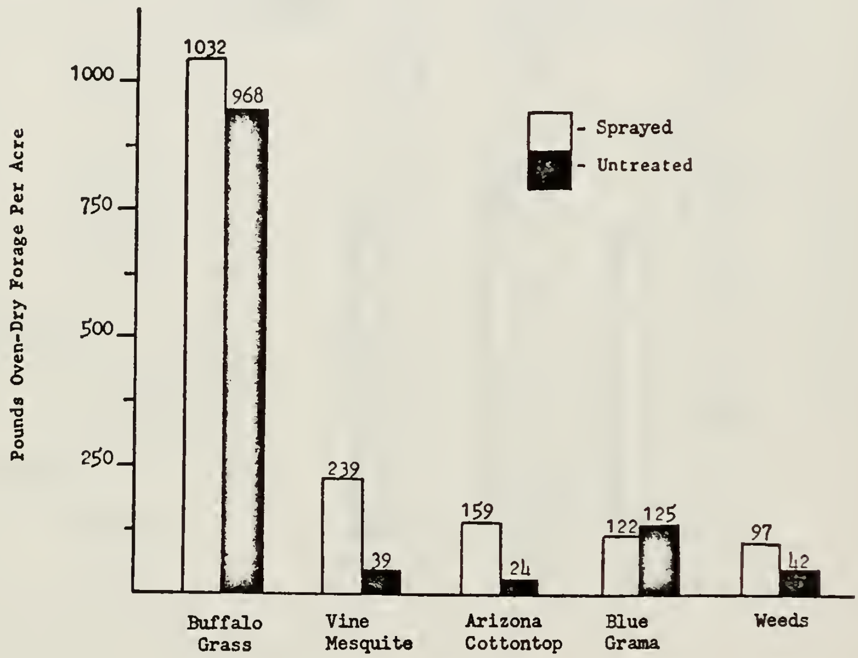


Table 22. Estimated grazing rate of rangeland by years before and after mesquite spraying (Workman et al., 1965).

Year	Upland site			Bottomland site		
	Acres per animal unit	AUM'S per acre[b]	Pasture observations	Acres per animal unit	AUM'S per acre[b]	Pasture observations
	— — — — — Number — — — — —					
Prior to spraying[c]	22.0	.545	16	20.0	.600	8
Year sprayed	21.2	.565	16	20.6	.582	8
1st year after spraying	17.0	.706	12	16.5	.727	6
2nd year after spraying	17.0	.706	9	16.5	.727	5
3rd year after spraying	17.0	.706	9	16.9	.710	5
4th year after spraying	17.6	.682	8	17.3	.694	4
5th year after spraying	18.4	.652	6	17.7	.678	3
6th year after spraying	19.0	.632	6	18.2	.659	3
7th year after spraying	19.4	.619	6	18.6	.645	3
8th year after spraying	19.7	.609	5	19.2	.625	2
9th year after spraying	20.0	.600	5	19.6	.612	2
10th year after spraying	20.4	.588	5	20.0	.600	2
11th year after spraying	21.0	.571	2	20.4	.588	1
12th year after spraying	22.0	.545	2			

[a]These data represent the average grazing rates over many upland and bottomland range sites in Throckmorton and Shackelford Counties, 1949-62.
[b]Animal unit months of grazing utilized per acre annually is obtained by dividing 12 by the acres required per animal unit.
[c]This is the control grazing rate.

a steady decline, increased forage was seemingly related to climate during the year. For example, grass yield increased only 2% the second year after spraying over unsprayed plots compared to 26% increased grass yields due to 2,4,5-T spraying the third year after treatment. Grass yields dramatically increased with both reduced mesquite canopy cover and with increased proportion of plants apparently killed the year of 2,4,5-T application (Table 23). Overall, this study showed that 2,4,5-T spraying increased perennial grass yields 22% for the 5 years included. From a similar study with mesquite sprayed in 1969 or 1970 at four ranch locations (Table 24), grass yields in 1971 were 63% greater on aerial sprayed pastures (Fisher et al., 1972).

Freeman et al. (1978) attempted to show economically the value of mesquite control to a ranching enterprise in the Texas Rolling Plains. Their analysis showed that rancher income could be significantly enhanced if mesquite control could provide as much as 21% increased forage production over 7 years. Tables 25 and 26 show expected net returns with brush control yielding 11, 21, or 31% increases in forage production at cattle prices compared to those early in 1978. From the articles reviewed, one could reasonably expect the 21% grass increase for 7 years in west Texas.

In south Texas, 2,4,5-T appears less useful than combinations of herbicides because of the regorwth of brush species not well controlled by 2,4,5-T alone. Nevertheless, preliminary indications from Scifres et al. (1977) are that even there, 2,4,5-T increases grass production the first year after spraying. Production of native grasses following aerial application of 1.12 kg/ha of 2,4,5-T, 2,4,5-T + dicamba, or 2,4,5-T plus picloram to a mixed brush (*Prosopis-Acacia*) community was significantly increased by all herbicide treatments the year of application, by the

Table 23. Expected annual increases in perennial grass yield (lb/acre) in relation to degree of mesquite infestation and proportion of mesquite controlled in west Texas (Dahl et al., 1978).

Honey mesquite trees unsprouted (%) fall of year sprayed	Honey mesquite canopy cover (%)				
	10	20	30	40	50
40					
50				30	200
60			70	250	420
70		120	300	470	650
80	160	340	520	690	870
90	390	560	740	920	1090
100	610	780	960	1140	1310

[1] Yield increases (y) were determined by the formula Y = 17.6 (% canopy cover) + 22.2 (% root kill) − 1787. (R^2 = 0.78).

Table 24. Influence of aerial spraying on yields of grass and forbs (Fisher et al., 1972).

Location	Pounds per acre, air dry, 1971			
	Aerial sprayed		Untreated	
	Grass	Forbs	Grass	Forbs
Vernon	1,048	140	972	88
Garden City	3,212	160	1,056	920
Guthrie	1,576	300	992	592
Menard	1,004	120	1,186	72
Total	6,840	720	4,206	1,672
Avg	1,710	180	1,052	418

Table 25. Change in yearly net returns as a result of brush control with cattle prices at the fourth level (Freeman et al., 1978).

Year	Percent Increase in Range Forage Production		
	11%	21%	31%
	----------Dollars----------		
1	-2,860	-2,860	-2,360
2	3,881	7,389	10,914
3	3,881	7,385	10,892
4	3,881	7,389	10,845
5	3,827	7,389	10,790
6	3,827	7,335	10,791
7	3,827	7,334	10,790

1/ 400 pound calves @$.50/lb.; 650 pound calves @$.48/lb.; 800 pound calves @$.46/lb.; cull cows @$.36/lb.

Table 26. Present value of economic benefits associated with a $20,000 investment in brush control, with cattle prices at fourth level (Freeman et al., 1978).

Income Tax Rate %	Rate of Return on Investment: Before Tax %	After Tax %	Net Present Value of Brush Control: 11% Increase in Forage Production[2/]	21% Increase in Forage Production	31% Increase in Forage Production
			---------------------	Dollars	---------------------
15	7	5.9	-4,661	9.196	22,940
20	7	5.6	-4,383	8,847	21,969
25	7	5.3	-4,106	8,478	20,958
30	7	4.9	-3,829	8,088	19,905
35	7	4.6	-3,552	7,676	18,811
40	7	4.2	-3,275	7,242	17,672
15	10	8.5	-6,287	6,224	18,636
20	10	8.0	-5,935	6,074	17,988
25	10	7.5	-5,582	5,903	17,296
30	10	7.0	-5,225	5,711	16,559
35	10	6.5	-4,866	5,495	15,773
40	10	6.0	-4,505	5,256	14,938

1/ 400 pound calves @ $.50/lb.; 650 pound calves @ $.48/lb.; 800 pound calves @$.46/lb.; cull cows @ $.36/lb.

2/ Brush control unprofitable at this range forage response level after discounting and taxes.

herbicide combinations during the second year, but only by 2,4,5-T plus picloram the third year after treatment. Defoliation of woody plants in years of above-average rainfall resulted in favorable grass production regardless of herbicide (Fig. 10 and Table 27). Forb production was reduced by all herbicides the year of treatment and by 2,4,5-T plus picloram the year following application, but was not reduced by any treatment during the third growing season (Table 28).

Mesquite infested rangelands in west Texas apparently produce about 1100 lb/acre of grass by mid-summer. Rangeland with mesquite controlled by 2,4,5-T can be expected to produce an average of approximately 1500 lb/acre by mid-summer. Although increased grass production was usually greatest the year after spraying, extra production of about this magnitude can be expected for an average of 4 years or more (Workman et al. 1965; Robison et al., 1970; Fisher et al., 1972; Dahl et al., 1978). Whereas Martin (1963) reported that as few as 15 to 25 velvet mesquite trees/acre in Arizona could reduce grass production by half, 25 more mesquite trees/acre in west Texas apparently has little influence on perennial grass production (Dahl et al., 1978).

Nevertheless, the degree of mesquite kill obtained by herbicide application is extremely important in providing extra grass production. Dahl et al. (1978) showed that with a honey mesquite canopy of only 10% that if as many as 30% of the trees began sprouting the year of 2,4,5-T application no extra grass was produced (Table 29). If the spray prevented all trees from sprouting, 610 lb of extra grass could be expected. On the other hand, with a 50% mesquite canopy, 30% of the trees could resprout the year of application and one could still expect 650 lb of extra grass/acre over a 4 year period. The Dahl et al. (1978) research showed that an average of 24% of the 2,4,5-T sprayed mesquite

Fig. 10. Cumulative oven-dry grass production during four grazing periods in 1973, 1974, and 1975 after aerial application of 2,4,5-T; 2,4,5-T + dicamba; or 2,4,5-T + picloram in 1973 at 1.12 kg/ha to mixed brush on a Sarita fine sandy loam near Raymondville (Scifres et al., 1977).

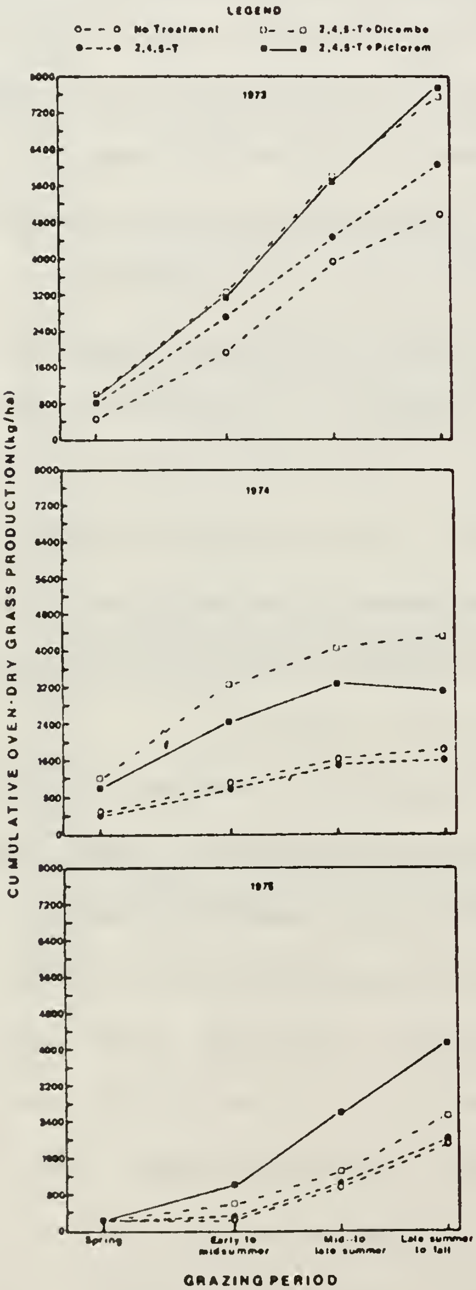


Table 27. Cumulative production and utilization (oven dry) of range grasses by early summer 1 yr after aerially applying 2,4,5-T alone and in combination with dicamba or picloram in May, 1974 to mixed brush on a Lomalta clay loam near Raymondville, Texas (Scifres et al., 1977).

Treatment		Range forage[a]	
Herbicide(s)	Rate (kg/ha)	Produced (kg/ha)	Consumed (kg/ha)
None	0	717 a	397 a
2,4,5-T	1.12	1,254 b	858 b
2,4,5-T dicamba	0.56 + 0.56	1,202 b	967 b
2,4,5-T + picloram	0.56 + 0.56	1,818 c	1,494 c

[a]Means followed by the same letter are not significantly different at the 5% level according to Student-Newman-Keuls' test.

Table 28. Forb production (oven dry) in October of 1973, 1974, and 1975 after aerially applying 2,4,5-T alone and in combination with dicamba or picloram in May, 1973 to mixed brush on a Sarita fine sandy loam near Raymondville, Texas. (Scifres et al., 1977).

Treatment		Forbs produced[a]		
Herbicide(s)	Rate (kg/ha)	1973 (kg/ha)	1974 (kg/ha)	1975 (kg/ha)
None	0	500 a	110 bc	506 a
2,4,5-T	1.12	225 b	180 bc	492 a
2,4,5-T dicamba	0.56 + 0.56	90 c	210 b	511 a
2,4,5-T + picloram	0.56 + 0.56	20 d	89 c	425 a

[a]Means followed by the same letter are not significantly different at the 95% level according to Student-Newman-Keuls' test.

Table 29. Expected annual increases in perennial grass yield (lb/acre) in relation to degree of mesquite infestation and proportion of mesquite controlled in west Texas (Dahl et al., 1978).

Honey mesquite trees unsprouted (%) fall of year sprayed	Honey mesquite canopy cover (%)				
	10	20	30	40	50
40					
50				30	200
60			70	250	420
70		120	300	470	650
80	160	340	520	690	870
90	390	560	740	920	1090
100	610	780	960	1140	1310

[1] Yield increases (y) were determined by the formula Y = 17.6 (% canopy cover) + 22.2 (% root kill) − 1787. (R^2 = 0.78).

trees resprouted by fall of the year sprayed and that 19% of the trees were permanently killed (Table 30). These values are probably very close to the long time average of 2,4,5-T sprayed honey mesquite trees throughout the High and Rolling Plains of Texas. While paying for this amount of honey mesquite control when cattle prices are low strictly from extra forage production would be marginal, both Freeman et al. (1978) and Workman et al. (1965) indicate that it would be very worthwhile if calf prices are as much as $0.50/lb. If one considers that many ranchers consider the labor savings in gathering and handling livestock worth $1.00/acre (Hoffman, 1975), that mesquite uses and transpires about 43% of the rain falling on the Rolling Plains of Texas (Gillette, 1967), and that Texas brush uses more water annually than is presently used by all industrial and municipal purposes (Rechinthin and Smith, 1967) (Tables 31 through 36), it is easily understood why mesquite control is an important topic in Texas. Because velvet mesquite inhibits grass production more in Arizona than honey mesquite does in Texas, it is also easy to see why mesquite management and control has had high priority also in Arizona. Based on the lack of available literature, role of mesquite on forage yield and livestock production has been little researched in New Mexico. However, the principles from Texas and Arizona research should apply reasonably well to mesquite infestations in New Mexico.

Research reviewed for this section was entirely limited to those studies designed to evaluate mesquite's role in competing with forage and livestock production. Values that mesquite has for cover, food, esthetics, etc. were not evaluated.

Table 30. Differences in perennial grass yields due to aerial application of 2,4,5-T to honey mesquite on Texas Rolling Plains rangeland from 1970 to 1975 (Dahl et al., 1978).

Site	Initial canopy cover (%)	Trees/ acre	Root kill 1st year (%)	Root kill 2nd year (%)	Grass yield differences (year after spraying): 2 mo. after spraying	1st	2nd	3rd	4th	Average
Shallow redland[1]	5	165	80	28		210	180	120	−380	30
Deep hardland[2]	12	206	85	40		−390	80	280	540	130*
Deep hardland[3]	21	630	80	40	1210	490	170	280	[4]	540*
Valley[1]	28	425	68	4		960	−330	330	40	250
Deep hardland[1]	34	625	65	8		660	170	480	[4]	440
Deep hardland[1]	36	665	92	12		2000	540	410	390	840*
Deep hardland[1]	54	1360	44	0		230	−610	410	[4]	10
Means	27	582	76	19		594	29	330	148	320

[1] Kent County.
[2] Tom Green County.
[3] Lynn County.
[4] Plots lost due to mechanical disturbance.
* Indicates that honey mesquite sprayed with 2,4,5-T resulted in significantly ($P \leq 0.05$) more perennial grass prodduction over the years sampled.

Table 31. Major woody plants of the north central prairie, cross timbers and central basin resource areas (Rechinthin and Smith, 1967).

Name	Acres by Density		
	Light	Medium	Dense
All woody plants	384,000	874,200	4,367,600
Post oak and others	733,800	632,500	1,362,600
Mesquite	900,400	1,421,500	1,793,600
Junipers	805,000	326,900	170,400
Cactus	1,568,100	194,100	26,600
Whitebrush	652,900	235,300	281,900
Live oak	735,800	588,100	74,600
Saltcedar	800	1,000	23,000

Table 32. Expected saving of water by watersheds, north central prairie, cross timbers, and central basin areas (Rechinthin and Smith, 1967).

River	Acre-feet
Brazos	473,900
Colorado	404,000
Red	211,700
Trinity	183,000
	1,272,600

Table 33. Major woody plants of the Edwards Plateau (Rechinthin and Smith, 1967).

Name	Acres by Density		
	Light	Medium	Density
All woody plants	1,563,300	9,050,000	10,968,900
Mesquite	6,107,900	3,884,500	1,907,200
Junipers	5,796,600	5,349,400	1,885,900
Live oak	4,466,200	4,264,600	784,600
Shin oak	3,815,700	722,700	154,100
Cactus	14,509,200	878,400	137,300
Post oak	1,073,000	130,400	11,400
Whitebrush	322,000	153,800	49,200
Saltcedar		7,000	28,300

* Many other species, such as Texas persimmon, mescalbean, guajillo, lotebush, coyotillo, catclaw acacia, and creosotebush are important locally but not shown in this table. They are included in the ''All woody plants''.

Table 34. Water saved by watersheds, Edwards Plateau land resource area (Rechinthin and Smith, 1967).

River	Acre-feet
Eastern Edwards Plateau	
Colorado	715,000
Guadalupe-San Antonio	330,000
Nueces	330,000
Western Edwards Plateau	
Colorado	70,000
Rio Grande-Pecos	248,400
	1,693,400

Table 35. Major woody plants in the Rolling Plains land resource area (Rechinthin and Smith, 1967).

Name	Acres by Density		
	Light	Medium	Dense
All woody plants	2,003,700	4,673,100	8,259,100
Mesquite	2,184,400	4,182,300	4,164,600
Shin oak	402,600	215,800	746,200
Sand sagebrush	1,582,500	1,292,000	616,500
Cactus	1,825,800	435,800	231,600
Junipers	630,500	1,401,300	663,200
Saltcedar	120,200	77,800	89,700

* Other locally important species not shown as separate acreages are lotebush, yucca, and catclaw acacia.

Table 36. Expected annual saving of water by watersheds, Rolling Plains (Rechinthin and Smith, 1967).

River	Acre-feet
Brazos	495,500
Colorado	443,500
Red	835,000
Canadian	413,000
	2,187,400

Ueckert, D. N. and H. A. Wright. 1971. Effect of wood boring insects on mesquite wood, p. 23. In, Noxious Brush and Weed Control Research Highlights. ICASALS Spec. Rep. No. 51. Texas Tech University. Lubbock. (Asst. Prof. and Assoc. Prof., Dep. Range and Wildlife Manage., Texas Tech University; research conducted near Post, Texas).

A field study involving eight treatments and 10 replications was begun in late June, 1970 south of Post, Texas to study the succession of insects in mesquite wood following various methods of top-killing mesquite, and to determine the effects of wood boring insects on the ignition parameters of mesquite. One year after the treatments were applied, treated trees were ranked visually in the field according to the degree of damage by flat-headed wood borers (Buprestidae) and branch borers (Bostrichidae). Wood samples from each treatment were also collected and actual counts of wood borer tunnels were taken from cross-sections sawed from branches of various sizes. Trees girdled with a chain saw had heaviest activity by both kinds of insects while the untreated trees had almost no activity. Activity by both kinds of insects was heavier on trees basally treated with diesel plus 2,4,5-T. Trees burned with diesel supported more activity than those burned with butane. Wood borer activity in trees that had been sawed off and laid on the soil surface was relatively low, probably due to temperatures unfavorably high for these insects. Activity was low in trees sprayed with 2,4,5-T and the wood in these trees appeared extremely hard and well cured. Insects are being reared for identification from wood samples collected from each treatment, and ignition characteristics of wood samples will be correlated with wood borer activity.

Morey, P. R., R. E. Sosebee, and B. E. Dahl. 1976. Histological effects of ethephon and 2,4,5-T on mesquite. Weed Sci. 24:292-297. (Assoc. Prof., Dep. Biology, Assoc. Prof. and Prof., Dep. of Range and Wildlife Manage., Texas Tech University; research conducted at Texas Tech University).

Six week-old honey mesquite (*Prosopis glandulosa* (Torr.) var. *glandulosa*) seedlings were treated with various concentrations of ethephon (2-chloroethylphosphonic acid) and 2,4,5-T (2,4,5-trichlorophenoxy)acetic acid) alone and in combinations to determine

Morey et al. 1976 (con't.)

effect on stem mortality under greenhouse conditions. Ethephon alone at 0.05 g/liter brought about defoliation and a reduction in xylem tissue formation but did not affect the histological development of the stem tissue. Treatment with 2,4,5-T alone at 3.2 g/liter resulted in 40% stem mortality along with the formation of abnormal xylem tissue of reduced thickness. A combination of ethephon (0.05 g/liter) and 2,4,5-T (3.2 g/liter) significantly increased mesquite mortality. This was associated with a further reduction in xylem thickness, abnormal development of the xylem, abnormal positional relationships of vascular tissues, and initiation of adventitious roots. This study showed that ethephon in combination with 2,4,5-T was more effective than either treatment alone in promoting the disruption of the tissue systems of the stem and in increasing control of mesquite seedlings.

SUMMARY AND CONCLUSIONS

The literature is devoid of studies related to the aesthetic value of spraying mesquite. Mesquite sprayed with phenoxy herbicides degrade very slowly, in fact, sprayed trees that have been killed may remain standing for years. Apparently, this is related to the anatomical and physiological response to the auxin-type herbicides. Generally, trees sprayed with 2,4,5-T have a higher percentage of fiberous tissue in the wood and a lower percentage (almost none) of starch grains in the parenchyma cells (Morey et al., 1976). Therefore, insect activity is essentially eliminated (Ueckert, 1971).

In contrast, trees treated with tebuthiuron respond quite differently. Insect activity begins almost immediately upon response to the herbicide (R. E. Sosebee, unpublished data). Many trees are completely decomposed within 5 years after treatment with tebuthiuron and it is difficult to determine any pre-existence without knowledge of trees in the area.

Mesquite trees with small diameter trunk treated with fuel oil (primarily diesel) also decay relatively rapid. But, trees with large diameter trunks may remain standing for many years.

A study that is presently in progress will attempt to evaluate the potential of shredding mesquite trees and then spraying the resprouts. Large, unsightly trees are removed by shredding. Presumably, resprouts will be easier to control and will subsequently be broken off at ground level, to eventually decompose or be broken into small pieces by livestock and wildlife.

Spraying mesquite has a tendency to leave aesthetically displeasing dead trees remaining (unless the area is chained following spraying), whereas mechanical treatments and often fire remove the old stems.

III. Pollution and Toxic Hazards

A. Toxicity

1. Humans

Kimmig, J. and K. H. Schulz. 1957. Chloracne from chlorinated aromatic cyclic ether. Chem. Abstr. 52:4026d. (Dermatologica 115:540-546; 1957). (Credentials unknown; study conducted at Univ. of Hamburg, Eppendorf, Germany).

Occupational chloracne was observed in 31 workers engaged in the production of 2,4,5-trichlorophenol and its transformation into 2,4,5-trichlorophenoxyacetic acid and esters. From animal experts it was shown that the toxic action was not due to trichlorophenol but to the product formed by the alk. hydrolysis of 1,2,4,5-tetrachlorobenzene. Tri- and tetra-chlorodibenzofuran and tetra-chlorodibenzofuran were also very active skin irritants. 2,3,6,7-tetrachlorodibenzodioxime was isolated from the byproducts, and its formation from sodium trichlorophenolate was established.

Courtney, K. D., D. W. Gaylor, M. D. Hogan, H. L. Falk, R. R. Bates, and I. Mitchell. 1970. Teratogenic evaluation of 2,4,5-T. Science 168(3933):864-866. (Credentials unknown; laboratory studies conducted at Nat. Inst. of Environ. Health Sci., North Carolina and Nat. Cancer Inst., Maryland).

The herbicide 2,4,5-trichlorophenoxyacetic acid is teratogenic and fetocidal in two strains of mice when administered either subcutaneously or orally and in one strain of rats when administered orally. The incidences of both cystic kidney and cleft palate were increased in the C57BL/6 mice as well as the incidence of cleft palate in the AKR mice. The incidence of cystic kidney was also increased in the rats. In addition, an increase in the ratio of liver weight to body weight in the mouse fetus and the occurrence of hemorrhagic gastrointestinal tract in the rat fetus suggest that this compound also has fetotoxic properties.

Newton, M. and L. A. Norris. 1970. Herbicide usage. Science 168(3939):1606-1607. (Oregon State Univ., Corvallis, Oregon and US-FS Corvallis, Oregon; study conducted in Pacific Northwest, United States).

Galston has called for additional restrictions on use of phenoxy herbicides. His recommendation is based on preliminary evidence that these chemicals may be teratogenic. Galston says that a pregnant woman might be continuously exposed to 1 mg of herbicide /kg of body weight/day as a result of water contamination from defoliation operations in Vietnam. His estimate is based on an application rate of 27 lb of phenoxy herbicide/ acre (1 lb/acre = 1.04 kg/ha).

We have monitored a number of normal operational aerial spray projects in cool, temperate forests of the Pacific Northwestern United States where application rates of phenoxy herbicides do not exceed 4 lb/acre. Here, spray residues do not move into water in a constant process of contamination. During chemical brush control operations, small amounts of stream contamination occur during aerial application, but once this water leaves the treatment area, movement of additional herbicides to the stream is negligible. A combination of rapid degradation and resistance to leaching prevents stream contamination by herbicide residues after heavy rains. The likelihood of chronic exposure of man or animals to phenoxy herbicide residues from forest spraying seems remote.

The treatments that showed the teratogenic capacity of the phenoxy herbicides consisted of repeated high doses in mice and rats. Data pointing to human health hazards are limited in scope and quantity; more information is needed on the effects of phenoxy herbicides on humans. Toxicity is related to magnitude and duration of dose, and the assumption of chronic persistence and continuous flow of phenoxy herbicides into water is not supported by the available records. A long history of field use of phenoxy herbicides has demonstrated that they interfere little with the quality of the environment.

Regulatory agencies are under increasing pressure to restrict the use of some pesticides. An adequate assessment of hazard requires consideration of both the likelihood of exposure to a significant dose and the toxicity of the chemical. Any decision to further restrict the use of phenoxy herbicides in the United States must be based on careful consideration of risks both of use, and nonuse, of these valuable chemical tools.

Newton and Norris 1970 (con't.)

The scientific community certainly should support restrictions on the hazardous use of any chemical. Equally, this community should support retention of chemical land management tools that research and long experience have demonstrated to be safe. Our studies of normal use of herbicides in Pacific Northwest forests indicate that further restrictions on these uses of the phenoxy herbicides are not justified.

Johnson, J. E. 1971. The public health implication of widespread use of the phenoxy herbicides and picloram. BioScience 21:899-905. (Vice President and Director of Research, Dow Chem. Co.; studies conducted by Dow Chemical Co.).

A variety of pesticides were reported in dust trapped in rain collected in Cincinnati in 1965 (Weibel et al., 1966). The dust was created by high winds over the southwestern United States and moved in a cloud in a northeasterly direction to Ohio where the precipitation occurred. An amount of 0.04 ppm of 2,4,5-T was determined to be present based on the air dried weight of the dust in the rain. No value was given for the amount of dust in the water.

If it were as much as 10%, the water could have contained a 4 ppb of 2,4,5-T. The significance of these findings are open to question, however, because of the (1) difficulties in analyzing for such small amounts, and (2) the alleged presence of a newer pesticide, ronnel, which is used in relatively small amounts as an additive to cattle feed and as a topical spray on cattle.

In conclusion, I set forth the opinion that the widespread use of phenoxy herbicides has produced no demonstrable evidence of potential harm to man. The herbicides used most widely (2,4-D and 2,4,5-T) are degraded and do not bioconcentrate. Moreover, the comparative toxicity shows these materials to be well tolerated in a variety of test systems. Man is not exposed to harmful concentrations. Impurities can be an important factor---particularly the chlorodibenzo-p-dioxins---but these can be controlled by proper manufacturing techniques. As always, care in application is an important part of safe practice both from the standpoint of man and the ecosystem in which these tools are used.

Milnes, M. H. 1971. Dioxin with a bang No. 2281. Food and Cosmetics Toxicol. 10(1):110-111. (Nature, Long. 232:395). (Credentials unknown; news and comments).

The potent teratogenicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin (dioxin), discovered as a result of its presence as a contaminant in the herbicide, 2,4,5-trichlorophenoxyacetic acid or 2,4,5-T has led to concern over the use of other chlorophenols in which dioxin or related compounds may occur. The health of workers manufacturing 2,4,5-T, including those involved in the intermediate synthesis of 2,4,5-trichlorophenol, has also come under scrutiny. Further information on possible exposure to dioxin is provided by the paper cited.

Following an explosion at a plant manufacturing 2,4,5-trichlorophenol by a process involving hydrolysis of 1,2,4,5-tetrachlorobenzene (TCB) with ethylene glycol and caustic soda, a white crystalline solid was isolated, which proved to be dioxin. It was subsequently found that hydrolysates of TCB heated beyond the normal temperature of 180° C reacted exothermically after residual ethylene glycol had distilled off, starting at about 230° C and progressing rapidly and controllably to 410° C. The distillate contained a solid which, by mass spectrography, nuclear magnetic resonance studies and gas-liquid chromatography, was identified as dioxin. In rabbits, this solid was lethal in a single oral dose of 10 μg/kg, and 1 μg/kg caused serious liver damage and chloracne.

It was concluded that dioxin was formed by the interaction of sodium 2,4,5-trichlorophenate molecules under the influence of the exothermic decomposition of sodium 2-hydroxyethoxide. At 180° C only minimal amounts of dioxin were formed even after prolonged heating. Hydrolysates of the three isomers of trichlorobenzene (which collectively contained all six dichlorophenol isomers) gave, like TCB, an exothermic reaction at 230° C, but the distillates and residues contained no detectable lower chlorodioxins and were not toxic to rabbits at a dose level of 1 g/kg.

As a result of these findings the process of 2,4,5-trichlorophenol production has been modified to give a final dioxin content of less than 1 ppm.

Sterling, T. D. 1971. Difficulty of evaluating the toxicity and teratogenicity of 2,4,5-T from existing animal experiments. Science 174(4016):1358-1359. (Dep. of Applied Mathematics and Computer Sci., Washington Univ. St. Louis, Missouri; literature review).

Yet, there are less than a dozen key reports each of studies on the toxicity of 2,4,5-T, dating back to the early 1950's for the most

Sterling 1971 (con't.)

part and on its teratogencity, mostly done in the last 2 years. Almost two decades have elapsed between these two series of experiments. Whereas the toxicity studies were done at some leisure and the teratogenicity studies had some aspect of emergency about them, they are indistinguishable in their lack of adequate statistical experimental design and analysis of data. Most of these experiments were performed with some variation and combination of different dose levels: different concentrations at which doses were applied, different vehicles that carried the doses, and different amounts of impurities (such as, especially, trichloro-2,3,7,8-tetrachlorodibenzo-p-dioxin,TCDD); and some were performed on different species or with different products coming from different manufacturers. Yet, the reports of these experiments analyzed by the 2,4,5-T Advisory Committee did not contain a single experiment that was designed to tell something about the effect of 2,4,5-T at very low doses, and attempted, by statistical analysis or mathematical techniques, to milk the available data (although inadequate) for whatever information could have been obtained about reactions of animals to very small doses. From the point of view of statistical sophistication practiced in this important field, much is to be learned from the aforementioned studies.

Wade, N. 1971. Decision on 2,4,5-T: leaked reports compel regulatory responsibility. Science 173(3997):610, 612-615. (Credentials unknown; news and comments).

The history of the 2,4,5-T episode is cogent evidence of the shambles into which the official decision-making machinery has lapsed. At two crucial points--the springing of the suppressed Bionetics report and the expose of the EPA advisory committee's whitewash--the intervention of outside scientists has been essential in keeping the government machinery on the rails and in motion. In short, the established machinery for protecting the public health has failed, and failed ignominiously.

Poland, A. P., D. Smith, G. Metter, and P. Possick. 1972. Working with 2,4,5-T, No. 2250. Food and Cosmetics Toxicol. 9:908-909. (Archs. Envir. Health 22:316; 1971). (Credentials unknown; news and comments).

The recent and continuing arguments about the possible teratogenic effects of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) have tended to overshadow other questions about possible hazards associated with its handling during manufacture or use. However, the paper

Poland et al. 1972 (con't.)

cited above reports on the medical problems associated with production of this herbicide, following a survey of 73 male workers in a 2,4,5-T factory. Chloracne, characterized by inclusion cysts, comedones and pustules, was found in 13 workers, and was correlated in severity with the presence of scarring, hyperpigmentation, hirsutism and complaints of eye irritation. There was also a significant correlation with hypomania, in contrast to the lethargy, dulled emotional response and apathy described previously in 2,4,5-T workers. Chloracne was commoner in maintenance men than in administrators, but there was no clear association with job location in specific parts of the plant, such as the 2,4,5-trichlorophenol-synthesizing area where the highest concentration of the by-product tetrachlorodibenzo-p-dioxin-p-dioxin ('dioxin') might be expected, or with duration of employment. Nor was there a correlation with coproporphyrin excretion; indeed, no overt clinical cases of porphyria cutanea tarda could be found, and of the 11 cases of uroporphyrinuria identified in the plant 6 yr previously only one was still suffering mildly from this disease. There was no difference from the general population in the function of the cardiovascular, pulmonary or haematological systems, but a high incidence of gastro-intestinal complaints and occasional inexplicable neurological defects may have been of some significance. In view of the hepatoxic effects of dioxin indicated in the following abstract, the occurrence of demonstrable liver dysfunction among these workers was remarkably low.

Some of these encouraging findings may have been due to a reduction in the dioxin content of the intermediate product, trichlorophenol, from a level of 10 to 25 ppm to less than 1 ppm about 6 months before the survey was undertaken, but in addition an increased awareness among workers of the necessity for safety precautions may also have played a part.

Gehring, P. J., G. G. Kramer, B. A. Schwetz, J. Q. Rose, and V. K. Rowe.

1973. The fate of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) following oral administration to man. Toxicol. and Applied Pharmacol. 26:352-361. (Chemical Bio. Res., Dow Chem. Co., Midland, Mich.; laboratory study conducted by Dow Chemical Co.).

Five human male volunteers ingested a single dose of 5 mg/kg without incurring detectable clinical effects. Concentrations of 2,4,5-T in plasma and its excretion were measured at intervals after ingestion. The clearances of 2,4,5-T from the plasma as well as its excretion from the body occurred via apparent first-order rate processes with half-lives of 23.10 and 23.06 hr, respectively. Essentially all of the 2,4,5-T was absorbed into the body and excreted unchanged in the urine. In the body, 65% of the 2,4,5-T resided in the plasma where 98.7% was bound reversibly to protein. The volume of distribution was 0.079 liters/kg. Utilizing the kinetic

Gehring et al. 1973 (con't.)

constants from the single dose experiment, the expected concentrations of 2,4,5-T in the plasma of individuals receiving repeated daily doses of 2,4,5-T were calculated. From these calculations, it was determined that the plasma concentrations would essentially reach a plateau after 3 days. If the daily dose ingested in mg/kg is A_o, the concentration in the plasma after attaining plateau would range from 12.7 A_o to 22.5 A_o μg/ml. This range would converge to approximately 17 A_o μg/ml as the daily dose A_o is distributed throughout the day.

Chapman, B. 1975. Sponsors of Science, Inc. on the safety of 2,4,5-T and dioxin. Pestic. Abstr. 8(7):433; 75:1496. (Clin. Toxicol. 7(4):413-421; 1974). (Credentials unknown; news and comments).

The safety and toxicity of 2,4,5-T and DDT are discussed in a letter written to Senator Gaylord Nelson. Both compounds are rated in comparative toxicity tables as among the least hazardous pesticides for human use. The actual amount of the technical (1,000,000 ppm) compound eaten determines the toxicity. Based on the acute oral toxicity expressed in mg/kg, a 125 lb woman would have to eat her body weight equivalent of material containing 380 ppm of 2,4,5-T to receive a lethal dose. Both 2,4,5-T and DDT in technical form are relatively non-toxic on skin contact (3800 mg/kg for 2,4,5-T and 2500 mg/kg for DDT). The toxicity of the dioxins contained in 2,4,5-T has little, if any, influence on the toxicity of the 2,4,5-T. There has been no human deaths and remarkably few human illnesses because of the agricultural or public health uses of either of these chemicals. There are no significant differences between the health of workers in 2,4,5-T or DDT manufacturing plants and the norm for the general population. Many researchers believe it would be completely erroneous to classify the 2,4,5-T currently manufactured as a teratogen. A no-effect of 50 mg/kg/day of 2,4,5-T containing less than 1 ppm dioxins is proposed as providing ample protection for human embryos.

Council for Agricultural Science and Technology. 1975. The phenoxy herbicides. Iowa State Univ., Ames. Report No. 39. 21p. (Studies conducted in United States).

The phenoxy herbicides, 2,4-D, 2,4,5-T, MCPA, silvex and related materials, are selective herbicides widely used in crop production and in the management of forests, ranges and industrial, urban and aquatic sites. These chemicals are related to naturally occurring plant growth regulators. They kill plants by causing malfunctions in growth processes. Broad-leaved plants are generally susceptible to the phenoxy herbicides, whereas most grasses, coniferous trees and certain legumes are relatively resistant.

The phenoxy herbicides are used to control broad-leaved weeds in wheat, barley, rice, oats, rye, corn, grain sorghums and certain legumes. Such uses increase yields, improve product quality and reduce production costs. The phenoxy herbicides are used in forests to suppress unwanted hardwood trees and brush, to reduce competition with conifers already established or to prepare sites for the regeneration of conifers. They are used on grazing lands to control unpalatable and noxious plants and to kill brush and small trees that reduce the productivity of pastures and ranges. 2,4-D and other phenoxys are used in canals, ponds, lakes and waterways to kill floating weeds such as water hyacinth, submerged weeds such as pondweeds, and emergent and shoreline plants such as cattails and willows. Industrial and urban uses include control of brush on utility and transportation rights of way, control of dandelions, plantains, and other weeds in turf and suppression of ragweed, poison ivy and other plants of public health importance.

The principal hazard in the use of the phenoxys is to crops and other valuable plants either within the treated area or nearby. Treated crops and forest trees can be injured through accidental overdosing, improper timing of treatments, unusual weather conditions, and other causes. Injury to nearby crops and ornamentals can result from drift of droplets or vapors of the spray. Such losses are largely preventable through the use of proper formulations and spray equipment and the exercise of good judgement.

The phenoxy herbicides are predominantly toxic to green plants and are much less toxic to mammals, birds, fish, reptiles, shellfish, insects, worms, fungi and bacteria. When properly used, they do not occur in soils and water at levels harmful to animals and microorganisms. They do not concentrate in food chains and do not persist from year to year in croplands. They are detectable only rarely in food and then only in insignificant amounts.

A highly poisonous kind of dioxin called TCDD is an unavoidable contaminant in commercial supplies of 2,4,5-T and silvex. The amount present in currently produced formulations of 2,4,5-T and silvex is not enough to alter the toxicological properties of these preparations or to endanger human health or to affect plants or animals in the environment.

The phenoxy herbicides are widely used because they are more efficient and usually less hazardous and less injurious to the environment than alternative methods. Use of these chemicals is estimated to reduce the cost of production of the crops on which

CAST 1975 (con't.)

they are used by about 5% and to reduce overall agricultural production costs in the United States by about 1%. Uses in forests and nonagricultural situations provide additional savings. If the phenoxys were no longer available, the cost of food, forest products, electric power, transportation and governmental services would be higher. These costs would be borne by consumers.

Kohli, J. D., R. N. Khanna, B. N. Gupta, M. M. Dhar, J. S. Tandon and K. P. Sircar. 1975. Absorption and excretion of 2,4,5-trichlorophenoxy acetic acid in man. Pestic. Abstr. 8(3):144. 75-0627. (Arch. Int. Pharmacodyn. Ther. 210(2):250-255; 1974). (Credentials unknown; laboratory study conducted at Ind. Toxicol. Res. Cent. Lucknow, India).

Absorption and excretion of 2,4,5-trichlorophenoxy acetic acid (2,4,5-T) by man following oral administration of 2, 3, and 5 mg/kg has been studied. The compound is absorbed readily from the gastrointestinal tract and is excreted mainly via the kidneys without undergoing any metabolic alteration in the system. Applying first order kinetics the $t_{1/2}$ of clearance of 2,4,5-T from plasma after oral administration of 5 mg/kg is 18.8 $\pm$ 3.1 hr.

Anonymous. 1976. The possible alternatives. Nature 263(5578):539. (Credentials unknown; news and comments).

The available alternatives to 2,4,5-T are 'Amcide', 'Glyphosate' and Krenite'; all three are effective brushwood killers. Amcide has been available in the UK since the early 1960s; Glyphosate is a more recent addition, and Krenite is at present only on sale in the US and West Germany.

These alternatives, when compared with 2,4,5-T, have some definite advantages. Amcide, made by Nissan in Japan, has an LD_{50} value for rats of 3,900 mg/kg; Glyphosate, made by Monsanto, has an LD_{50} value of 4,900 mg/kg. These toxicity ratings are well below that for 2,4,5-T (LD_{50} value 300 mg/kg). Krenite, made by Dupont, has an LD_{50} value of 24,000 mg/kg, a toxicity rating one eightieth of that for 2,4,5-T.

The reaction to produce Amcide presents none of the potential hazards associated with trichlorophenol manufacture in terms of toxic by-products. Information has not been made available for Glyphosate or Krenite production. However, in the case of Krenite the EPA considers its manufacture to conform to accepted safety standards, and in view of its comparatively low toxicity has declared it as safe for use even on land adjacent to domestic water supply and streams. The disadvantages associated with the three alternative are primarily those of cost. Amcide and Glyphosate are more expensive than 2,4,5-T when the concentrations of herbicide necessary to effect the same plant kill ratio are considered; Glyphosate is nearly five times as costly. Some potential buyers of Krenite consider that it, too, may be expensive when it is introduced on the UK market. The only other problem of any consequence relates to Amcide. In contrast to 2,4,5-T which is absorbed through leaves following spraying, Amcide must be applied to cut surfaces on plants. Its method of application is therefore considerably more labour intensive.

Hexachlorophene, the other major product derived from trichlorophenol, is a general poison effective in the control of gram-positive bacteria. In the cosmetics industry hexachlorophene is used as a preservative. For medical purposes hexachlorophene is used in the control of staphylococcal organisms. The bactericide has four main uses: treatment of acne and impetigo, cleansing of intact skin around burns or wounds pre-surgical washing, and cleansing of new-born infants, particularly the umbilical cord.

Its use, however, has been much reduced, and the industry is reported as being able to dispense with it altogether. Chlorhexidine--a bactericide now cleared for sale in the US--is used surgically in the UK as a skin cleanser, would steriliser and for presurgical washing. On the question of the cleansing of the newly born infant, however, there is a difference of opinion as to which of the two bactericides is the most effective.

Materinity clinics and nurseries are particularly open to bacterial crossinfection by the staphylococccal organisms. One of the most common is *S. aureus*. In the 1940s this organism was responsible for frequent epidemics in nurseries, with a consequent increase in infant mortality. When hexachlorophene was first marketed by Givaudan in the late 1940s it proved to be effective both in the routine containment of *S. aureus* and in controlling the organism in the case of an epidemic. As a result of its efficiency, hexachlorophene rapidly replaced the bactericide 'Triple Dye' in use at that time, to become the most widely used antibacterial agent in nurseries.

Two events in 1971 and 1972, however, caused users to reconsider their judgement. The first was a report by the EPA showing hexachlorophene to cause oedema and hindlimb paralysis in experiments on mice. The second was the death in France of 35 infants following the use of talcum powder containing 6% hexachlorophene. The neurological damage which led to the death of the children was caused by a twenty-fold increase of hexachlorophene concentration in the talc, the result of manufacturing error.

Anonymous 1976 (con't.)

Many maternity units in the UK have since reduced the amount of hexachlorophene used for infant washes. Currently less than half use hexachlorophene at all. Others rely on alcohol, used either alone or with chlorhexidine. Consultants at one cross-infection laboratory now recommend nurseries to avoid the use of hexachlorophene altogether for routine washes. The reasoning behind this recommendation lies in the evoluation of S. aureus itself, which has evolved through several forms since the 1940s and is now active as a complex of S. aureus.

The present generation of the bacterium is not causing serious epidemics in British hospitals which are fatal to children. Indeed the risk associated with hexachlorophene use is considered to present a greater threat than that represented by the staphlococcus itself. A further consideration is the fact that many British maternity units use a concentration of hexachlorophene to control S. aureus which is too low to kill the bacterium.

In the routine control of S. aureus chlorhexidine is as effective as hexachlorophene, and has the added advantage of an LD_{50} value ten times higher. Chlorhexidine is also reported to be just as efficient in controlling local epidemics of the present milder strain of the bacterium. It has not been tested, however, with more lethal strains of the staphylococcus, whereas hexachlorophene has been shown to control dangerous epidemics of S. aureus in the past. Some bacteriologists anticipate that chlorhexidine will prove to be equally effective, but are reluctant to recommend it unequivocally as an alternative until this has been demonstrated conclusively.

Although the principal purpose behind trichlorophenol production is the synthesis of 2,4,5-T and hexachlorophene, the chlorinated phenol is still used to some extent as a slime control agent in the paper making industry. It has never been as popular as pentachlorophenol, used for the same purpose, and what use it has had has been much reduced, due mainly to the criticisms of the unrestricted industrial use of polychlorinated biphenyls (PCBs) such as DDT, advanced by the environmental lobby.

In common with many industries which discharge effluent directly into rivers, the paper manufacturers have been particularly sensitive to the charge that their plant operating procedures are damaging to the environment. Because of the known risks associated with extensive PCB use, paper manufacturers in the UK have considerably reduced their use of all chlorinated phenol derivatives. Agents now preferred for the prevention of fungal growth include methylene bis thiocyanate together with some organobromine and organosulphur products.

III. Pollution and Toxic Hazards

A. Toxicity

1. Humans

SUMMARY AND CONCLUSIONS

Potential effect of 2,4,5-T and 2,3,7,8-tetrachlorodibenzo-p-dioxin (commonly called "dioxin") on humans was brought to public attention by research that was conducted by the Bionetics Research Laboratory in the late 1960's. This research indicated that 2,4,5-T, or dioxin, was teratogenic when given to mice subcutaneously (generally at higher dosages than one would ordinarily receive) in combination with dimethylsulfoxide (DMSO) (Courtney et al., 1970). Since the release of this information, there have been numerous charges and counter-charges concerning the teratogenicity, and mutogenicity of 2,4,5-T in humans, but very little research has been reported in the literature. Much of the concern has arisen from herbicides used by the military in Viet Nam, which are similar, in name only, to those used in the U.S.

Johnson (1971) reported that man has very little exposure to phenoxy herbicides through food. The acute oral toxicity of the phenoxy herbicides to mammals ranges from 100 mg/kg to 2000 mg/kg (CAST, 1975). 2,4,5-T administered orally to male humans (2 to 5 mg/kg) was absorbed from the gastrointestinal tract and excreted unchanged via the kidneys in the urine (Gehring et al., 1973; Kohli et al., 1975; CAST, 1973). Chapman (1975) pointed out that, a 125 lb woman would have to consume her body weight equivalent of material containing 380 ppm of 2,4,5-T to receive a lethal dose, based on acute oral toxicity levels. Dioxins contained in 2,4,5-T have little, if any, effect on the toxicity of 2,4,5-T (Chapman, 1975).

Chapman also notes there have been no human deaths and "remarkably few" human illnesses resulting from the proper use of 2,4,5-T for either agricultural or public health purposes.

Chloracne has been observed in workers engaged in manufacturing 2,4,5-T (Poland et al., 1972). However, Kimmig and Schulze (1957) reported that chloracne resulted from alkaline hydrolysis of 1,2,4,5-tetrachlorobenzene instead of production of trichlorophenols. Subsequent research has revealed that 2,4,5-T (technical form; 3800 mg/kg) is non-toxic on skin contact (Chapman, 1975; Johnson, 1971). Johnson (1971) also noted no chromosomal effects on individuals engaged in manufacturing 2,4,5-T.

Surveys of several individuals working with 2,4,5-T since its release in the 1940's indicate no personal effects or effects on their family, including offsprings.

III. Pollutant and Toxic Hazards
A. Toxicity
2. Mammals

Mitchell, J. W., R. E. Hodgson and C. F. Gaetjens. 1944. Tolerance of farm animals to feed containing 2,4-Dichlorophenoxyacetic acid. J. Anim. Sci. 5:226-232. (Physiologist, Bureau of Plant Industry, Soils and Agr. Engineering, Dairy Husbandman, Bureau of Dairy Industry, and Scientific Aid, Bureau of Plant Industry, Soil, and Agr. Engineering, Beltsville, Md.; research conducted at Beltsville).

Sheep and cows grazed pasturage treated with a liberal application of weed killer (2,4-dichlorophenoxyacetic acid and Carbowax mixture). There was no apparent reduction in its palatability. The 2,4-D consumed either on pasture grass eaten by sheep and cows or in the ration fed to a cow at the rate of 5.5 g daily, produced no apparent harmful effects in the health and performance of the animals. Post-mortem examinations revealed no pathological conditions in cows grazing on pasture treated with 2,4-D nor was this material found to be present in the liver, kidney or fatty tissues of a cow fed 2,4-D.

By means of a biological method of assay, the presence of 2,4-D was demonstrated in the blood serum of a cow fed 5.5 g of this material daily for 106 days. Results of these tests indicate that the 2,4-D probably occurred as a water-soluble salt.

The 2,4-D was not found to be secreted into the milk nor was it found in the blood serum of a calf fed milk from the cow that received it in her ration.

It is concluded from these data that the amount of 2,4-D that might be consumed by cows or sheep from pasturage sprayed with this material to kill weeds would not be injurious.

The present experiments are based on the use of purified 2,4-D together with Carbowax and, while they indicate that the acid is not toxic, the results are not applicable to proprietary formulations that might contain other ingredients.

Drill, V. A. and T. Hiratzka. 1953. Toxicity of 2,4-dichlorophenoxy acetic acid and 2,4,5-trichlorophenoxyacetic acid. Arch. Indust. Hygiene Occupational Medicine 7:61-67. (Ph.D., M.D., Dep. Physiology and Pharmacology, and M.S., Dep. Pathology, Wayne Univ. College of Medicine, Detroit, Mich.; research conducted at Wayne Univ. College of Medicine).

The acute oral $L.D._{50}$ of 2,4-dichlorophenoxyacetic acid (2,4-D) in dogs was approximately 100 mg/kg of body weight. Doses in this range or higher produced a definite myotonia accompanied by anorexia and weight loss. The acute oral $L.D._{50}$ for 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) was in the range of 100 mg/kg or higher. Such toxic doses produced only signs of a mild spasticity.

All dogs survived the oral feeding of 2, 5, or 10 mg/kg of 2,4-D or 2,4,5-T 5 days a week for a period of 90 days. These doses did not produce any symptoms or changes in body weight, organ weights, or blood count.

Three of the four dogs receiving repeated doses of 20 mg/kg of 2,4-D died, and all four dogs receiving 20 mg/kg of 2,4,5-T died during the study. Toxicity to 2,4-D at the dosage level was accompanied by bleeding from the gums, necrotic changes in the buccal mucosa, and some difficulty in chewing and swallowing, but there was only little evidence of clinical myotonia. A terminal fall in the percentage of lymphocytes was observed in three of the animals.

Death during the repeated administration of 2,4-D or 2,4,5-T was not related to pathological changes in the liver, kidney, or other organs examined.

Rowe, V. K. and T. A. Hymas. 1954. Summary of toxicological information on 2,4-D and 2,4,5-T type herbicides and an evaluation of the hazards to livestock associated with their use. Am. J. Vet. Res. 15:622-629. (M.S., Biochemical Research Dep., and D.V.M., Agr. Chem. Research Laboratory, The Dow Chemical Co., Midland, Mich.; research conducted in Midland, Mich.).

1) The acute oral $l.d._{50}$ values for 2,4-D, 2,4,5-T, and their various derivatives commonly used in herbicidal preparations fall in the range of 300 to 1,000

Rowe and Hymas 1954 (con't.)

Generally, dogs are more susceptible and chicks are more tolerant of this type of material. On a weight basis, the toxicity to cattle appears to be quite similar to the toxicity to ordinary laboratory animals.

2) The acute oral $L.D._{50}$ values for commercial formulations of 2,4-D and 2,4,5-T type materials are approximately proportional to their content of active ingredient. The "inert ingredients" do not appear to contribute materially to the oral toxicity of the formulations.

3) Data available indicates that the 2,4-D and 2,4,5-T type herbicides have a low chronicity.

4) MCP (2-methyl-4-chlorophenoxyacetic acid) and silvex (2-(2,4,5-trichlorophenoxy) propionic acid) and their herbicidal derivatives appear to be slightly less toxic than the corresponding 2,4-D and 2,4,5-T type materials.

5) The hazard to livestock and wildlife associated with the use as recommended of herbicides containing 2,4-D, 2,4,5-T, MCP, and silvex is negligible. It should be recognized, however, that toxic amounts of these materials can be obtained if animals have access to spray tanks or other containers of the materials.

Goldstein, H. E. and J. F. Long. 1958. Observations on cattle, sheep and swine exposed to 2,4-D, 2,4,5-T, and dalapon herbicides. 1958. North Central Weed Control Conf., Proc. 15:28-29. (Titles unknown, Ohio Dep. Agr., Reynoldsburg, Ohio; research conducted at the Diagnostic Laboratory, Reynoldsburg).

St. John, L. E., D. E. Wagner, and D. J. Lisk. 1964. Fate of atrazine, kuron, silvex, and 2,4,5-T in the dairy cow. Dairy Sci. 47:1267-1270. (Dep. Entomology and Animal Husbandry, Cornell University, New York; research conducted at Cornell).

Atrazine (2-chloro-isopropylamino-6-ethyl-amino-s-triazine), kuron (propylene glycol butyl ether esters of 2-(2,4,5-trichlorophenoxy) propionic acid), silvex (2-(2,4,5-trichlorophenoxy) propionic acid), and 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) are often used for weed and brush control in the vicinity of forage crops. The reality of contaimination of forage by drift or uptake prompted the study of the fate of these herbicides in the dairy cow.

St. John et al. 1964 (con't.)

No residues of these herbicides were found in the milk. About 2% of intact atrazine was eliminated in the urine. About 67% of the kuron was hydrolyzed and eliminated as silvex (sodium salt) in the urine. Within experimental error, silvex and 2,4,5-T appeared to be totally eliminated in the urine as salts.

Fang, S. C., M. L. Montgomery, and V. H. Freed. 1966. The metabolism and distribution of 2,4,5-trichlorophenoxyacetic acid in female rats. Toxicol. Appl. Pharmac. 22:317-318. (Titles unknown, Oregon State Univ.; research conducted at Oregon State Univ.).

C-labeled 2,4,5-trichlorophenoxyacetic acid (2,4,5-T-1-^{14}C) was fed po to adult rats at a dose of 0.04-10 mg/rat, and expired air, urine, feces and internal organs, and tissues were analyzed for radioactivity. No ^{14}C was found in the expired air during a 7-day period following dosing. During the first 24 hr $75 \pm 7\%$ of the radioactivity was excreted in the urine and $8.2 \pm 4.6\%$ in the feces. The average recoveries after 7 days were 85% in the urine and 11% in the feces. Between 90 and 95% of the radioactivity in the first and second day urine samples was unchanged 2,4,5-T. There was no significant difference in the rate of elimination between rats receiving 0.04, 1, or 10 mg of 2,4,5-T. Radioactivity was found in all organs and tissues examined. The maximum concentration in all tissues was generally reached 6 to 12 hr after dosing and then started to decline rapidly. The highest concentration of 2,4,5-T was found in the kidneys; the next highest was in the blood, lung, heart and liver, respectively. The average biological half-life of 2,4,5-T in the blood and vital organs was 3.5 hr. Very little radioactivity remained in the organs after 3 days. The excretion and tissue distribution of 2,4,5-T after multiple doses in pregnant rats were also investigated.

Courtney, K. D., D. W. Gaylor, M. D. Hogan, H. L. Falk, R. R. Bates, and I. Mitchell. 1970. Teratogenic evaluation of 2,4,5-T. Science 168:864-866. (First four authors, National Institute of Environmental Health Sciences, Research Triangle Park, North Carolina, and last two authors, National Cancer Institute, Bethesda, Md.; research conducted at the Bionetics Research Laboratories, Division of Litton Industries).

The herbicide 2,4,5-trichlorophenoxyacetic acid is teratogenic and fetocidal in two strains of mice when administered either subcutaneously or orally and in one strain of rats when administered orally. The incidences of both cystic kidney and cleft palate were increased in

Courtney et al. 1970 (con't.)

the C57Bl/6 mice as well as the incidence of cleft palate in the AKR mice. The incidence of cystic kidney was also increased in the rats. In addition, an increase in the ratio of liver weight to body weight in the mouse fetus and the occurrence of hemorrhagic gastrointestinal tract in the rat fetus suggest that this compound also has fetotoxic properties.

Kearney, P. C. 1970. Herbicides in the environment, p. 496-512. In, FAO Internal. Conf. Weed Control. (Biochemist, USDA-ARS, Beltsville, Md.; literature review).

One very controversial aspect of the present environmental situation concerns the continued use of pesticides in plant protection programs. The chlorinated hydrocarbon insecticides have come under heavy criticism due to their relatively long persistence in the environment, biomagnification through certain organisms, and their frequent detection in the food chain. By contrast, the organic herbicides have received relatively little criticism, primarily due to their low mammalian toxicity and short persistence under most environmental conditions. The most severe challenge to a major class of herbicides has resulted from a recently completed study on the teratogenicity of (2,4,5-trichlorophenoxy) acetic acid (2,4,5-T). At high feeding rates (113 mg/kg) 2,4,5-T was found to produce cleft palate, polycystic kidneys, and feticidal effects in certain mice (30). The situation with 2,4,5-T appears to be far more complex than originally suspected because certain toxic impurities known to be teratogenic have been detected. One impurity has been identified as 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD). The dioxin arises during the initial hydrolysis of tetrachlorobenzene to 2,4,5-trichlorophenol. The phenol is subsequently reacted with chloroacetic acid to form 2,4,5-T. Previously, the hexachlorodibenzo-*p*-dioxin was implicated in the chick-edema factor, but later the tetrachloro isomer was shown to be equally toxic to chicks (59). Whether 2,4,5-T or TCDD is the teratogen is still unclear at this time.

In this review we have two reasons to be concerned primarily with the phenoxy herbicides in the environment:

1. The controversy involving the possible teratogenicity of one or more of the phenoxy herbicides has developed.

2. We have more information on the phenoxy herbicides in the environment than on any other class of herbicides.

In logical sequence, the review considers the entry, persistence, and residues of (2,4-dichlorophenoxy) acetic acid (2,4-D) and 2,4,5-T and the influence of these compounds in the environment.

Binns, W. and L. Balls. 1971. Nonteratogenic effects of 2,4,5-trichlorophenoxyacetic acid and 2,4,5-T propylene glycol butal esters herbicides in sheep. Teratology 4:245. (Titles unknown, Poisonous Plant Research Lab., USDA-ARS, Logan, Utah).

Congenital deformities were not induced in any of the lambs from one group of eleven ewes maternally fed 100 mg/kg of body weight of 2,4,5-Trichlorophenoxyacetic acid nor from another group fed 100 mg/kg of body weight of 2,4,5-T propylene glycol butal esters. Both compounds were mixed in .5 lb of groung alfalfa meal and force fed via stomach tube daily from the fourteenth to thirtysixth day of gestation. A third group of five ewes was fed 2,4,5-trichlorophenoxyacetic acid at a rate of 113 mg/kg of body weight for different periods of gestation as follows: one ewe from the fourteenth to ninteenth day of gestation; two ewes from the fourteenth to twenty seventh day of gestation; and two ewes from the fourteenth to twenty ninth day of gestation. All five ewes gave birth to full-term, normal live lambs. The 2,4,5-trichlorophenoxyacetic acid contained 1 ppm of 2,3,7,8-tetrachlorodibenzo-p-dioxin.

Collins, T. F. X. and C. H. Williams. 1971a. Teratogenic studies with 2,4,5-T and 2,4-D in the hamster. Teratology 4:229. (Titles unknown, Bureau of Foods, Food and Drug Adm., Washington, D. C.; location where research conducted unknown).

Commercial samples of 2,4,5-trichlorophenoxy acetic acid were feticidal and teratogenic in the Golden Syrian hamster when administered orally on days 6 to 10 of organogenesis, and the incidence of effects increased with the content of the impurity, 2,3,7,8-tetrachlorodibenzo-p-dioxin. Abnormalities per live litter were clearly related to dose levels of 2,4,5-T in combination with dioxin. With dioxin, the abnormalities caused by 2,4,5-T consisted chiefly of absence of eyelid and poor head fusion. Dioxin contamination increased the level of hemorrhages in the liveborn, and also produced marked edema.

Terata were produced occasionally with 2,4-D, and the fetal viability per litter decreased but neither effect was clearly dose-related. Fused ribs were seen with the greatest frequency among the terata produced by 2,4-D.

Collins, T. F. X. and C. H. Williams. 1971b. Teratogenic studies with 2,4,5-T and 2,4-D in the hamster. Environ. Contam. Toxicol., Bull. 6:559-567. (Titles unknown, Div. of Toxicology, Dep. HEW-FDA, Washington, D. C.; laboratory studies conducted in Washington, D. C.).

Commercial samples of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) were feticidal and teratogenic in the golden Syrian hamster when administered orally on days 6 to 10 of organogenesis, and the incidence of effects increased with the content of the impurity, 2,3,7,8-tetrachlorodibenzo-p-dioxin (dioxin). Abnormalities per live litter were clearly related to dose levels of 2,4,5-T in combination with dioxin. With dioxin, the abnormalities caused by 2,4,5-T consisted chiefly of absence of eyelid and delayed head ossification. Dioxin contamination increased the level of hemorrhages in the liveborn, and also produced marked edema.

Terata were produced occasionally with 2,4-dichlorophenoxyacetic acid (2,4-D) and the fetal viability per litter decreased, but neither effect was clearly dose-related. Fused ribs were seen with the greatest frequency among the terata produced by 2,4-D.

Courtney, K. D. and J. A. Moore. 1971. Teratology studies with 2,4,5-trichlorophenoxyacetic acid and 2,3,7,8-tetrachlorodibenzo-p-dioxin. Toxicol. Appl. Pharmac. 20:396. (Credentials unknown).

The teratogenic effects induced by 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) in experimental animals have been attributed to the presence of the contaminant 2,3,7,8-tetrachlorodibenzo-p-dioxin ('dioxin'). (Cited in F.C.T. 1971, 9, 152; Sparschu et al. Fd. Cosmet. Toxicol. 1971, 9, 405 & 527). Teratogenicity tests in rats and rabbits on 2,4,5-T samples hardly contaminated with dioxin have yielded negative results. Although this negative finding was experienced in the present rat study, teratogenic effects were seen in three mouse strains treated with 2,4,5-T containing as little as 0.05 or 0.5 ppm dioxin.

Mice of the random bred CD-1 strain and of the inbred DBA/2J and C57Bl/6J strains were given daily subcutaneous (sc) injections of 50 to 150 mg 2,4,5-T/kg or 1 to 3 μg dioxin/kg in 100% dimethylsulphoxide (DMSO) on days 6 to 15 of pregnancy. In one experiment, the CD-1 strain was treated with a combination of 2,4,5-T (100 mg/kg/day) and dioxin (1 μg/kg/day) over the same period. Rats of the random-bred strain were given daily oral doses of 10 to 80 mg 2,4,5-T/kg in 15% sucrose solution or daily sc injections of 0.5 μg dioxin/kg in 100% DMSO during days 6 to 15 of pregnancy. Mice were killed on days 17 or 18 and rats on day of 20 of gestation. Both 2,4,5-T and dioxin produced cleft palate and kidney anomalies (nephrosis) in each of the three mouse strains, but no malformations or interference with postnatal growth

Courtney and Moore 1971 (con't.)

and development were seen in rats given 2,4,5-T. Dioxin produced kidney anomalies in the rats but not cleft palate. Combined 2,4,5-T/dioxin treatment in mice did not act synergistically.

Maternal liver-to-body weight ratio was increased in mice given 2,4,5-T (in all three strains) or dioxin (in the two inbred strains) but neither compound elicited this effect in rats.

Emerson, J. L., D. J. Thompson, R. J. Strebing, C. G. Gerbig, and V. B. Robinson. 1971. Teratogenic studies on 2,4,5-trichlorophenoxyacetic acid in the rat and rabbit. Food Cosmet. Toxicol. 9:395-404. (Titles unknown, Dep. Pathology and Toxicology, The Dow Chemical Co., Zionsville, Indiana; research conducted at the Human Health and Development Laboratories, Zionsville).

Groups of Sprague Dawley-derived rats received daily oral doses of 1,3,6,12 or 24 mg 2,4,5-T/kg on days 6 to 15 of gestation. Groups of New Zealand White rabbits received daily oral doses of 10, 20 or 40 mg 2,4,5-T/kg on days 6 to 18 of gestation. No clinical or gross pathological sign of adverse chemical effect was observed during the period of treatment or gestation in dams of either species treated with 2,4,5-T. Similarly, litter size, number of foetal resorptions, birth weights and sex ratios appeared to be unaffected by the chemical treatment. Detailed visceral and skeletal examinations of foetuses from the control groups and the groups given the highest dose of 2,4,5-T failed to reveal any teratogenic or embryotoxic effects. Under the conditions of this study, therefore, 2,4,5-T was not embryotoxic or teratogenic in the rat or rabbit.

King, C. T. G., E. A. Horigan, and A. L. Wilk. 1971. Screening of the herbicides 2,4,5-T and 2,4-D for cleft palate production. Teratology 4:233. (Titles unknown, National Inst. of Dental Research, Bethesda, Md.; location where research conducted unknown).

Our main interest in teratology is the production of cleft palate fetuses in order to study the etiology of the malformation under different experimental conditions. The compound was administered by gavage to Sprague-Dawley rats at critical stages of organogenesis. Observations were also made and recorded on second generation animals, which appeared grossly normal at birth and were allowed to survive, but received no further treatment. In addition "purified" and

King et al. 1971 (con't.)

technical grade 2,4,5-T was applied to Millipore filters that were then placed on the amniotic sac of the embryo. The following results were obtained. "Purified" 2,4,5-T intrauterinely applied to 93 embryos on any one day of gestation from day 12 to 16 at a dose range of 50 to 125 μg embryo resulted in no cleft palates. Substituting technical for the purified grade and using the same scheme as above on 118 embryos yielded 2 cleft palates on day 15. Forty five control rats delivered 442 normal fetuses, with a 3.5% resorption rate and an average litter size of 9.8. Administration of 2,4,5-T and/or combined with 2,4-D at a total dose range of 60 to 120 mg/kg to 245 rats yielded 2231 fetuses, 9 of which had cleft palate. The resorption rate was 2.6% and the average litter size was 9. Details of these experiments and those using the NIH all purpose mouse will be discussed, although the trends are similar to the results presented here.

Matlib, M. A., R. C. Kirkwood, J. D. E. Patterson. 1971. Binding of certain substituted phenoxy-acids by bovine serum albumin. Weed Res. 11:190-192. (Titles unknown, Dep. Biology and Dep. Biochemistry, University of Strathclyde, Glasgow, Scotland; research conducted in Scotland).

Moore, J. A. and K. D. Courtney. 1971. Teratological studies with 2,4,5-T and silvex. Teratology 4:236. (Titles unknown, Inst. Environ. Health Sci., Research Triangle Park, N. Carolina; location where research conducted unknown).

An earlier report, (Science, Vol. 168, 15 May 1970) found 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) to be teratogenic in mice and rats. It was later found that the sample of 2,4,5-T studied contained TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin) a toxic by-product formed during the manufacturing process. Subsequent studies using purified compounds found that 2,4,5-T and TCDD were teratogenic in CD-1, DBA/2J, and C57Bl/6J mice. Both compounds produced cleft palate and kidney malformations when administered subcutaneously on day 6 through 15 of gestation at a dose of 100 mg/kg. In the CD rag, 2,4,5-T was neither fetotoxic nor teratogenic. Cleft palates were also found in fetuses from CD-1 mice that received 100 mg/kg, free acid equivalent dosage of 2,4,5-T butyl ester, 2,4,5-T osooctyl ester, or 2,4,5-T propylene glycol butyl ether ester. Silvex (2,4,5-trichlorophenoxyproprionic acid) was not teratogenic in the CD-1 mouse and CD rat.

Pimental, D. 1971. Ecological effects of pesticides on non-target species. Exec. Office of the President. Office of Science and Technology. United States Government Printing Office. Washington, D.C. 220p. (Title unknown, Dep. Entomology and Limnology, Cornell University, New York; summary of published research).

Long, M. L. 1972. Residues in milk and meat and safety to livestock from the use of phenoxy herbicides in pasture and rangelands. Down to Earth 28(1):12-20. (Registration Specialist, The Dow Chemical Co., Midland, Mich.; research conducted by USDA and reported by an Industry Task Force on Phenoxy Herbicide Tolerances).

Residues of phenoxy compounds and of their respective phenolic moieties are not likely to occur in milk, meat, fat, or meat byproducts of cattle and sheep from agricultural use of these herbicides. Such residues would occur only under the unlikely circumstances when the animals are milked or slaughtered while actually ingesting freshly treated forage in pasture or rangeland treated at high rates of application. This conclusion is based on practical consideration of treatment rates, of dissipation of residues in forage and tissues, and of grazing restrictions on current labeling for these herbicides.

No harmful effect is likely to occur in livestock from grazing areas treated with phenoxy herbicides, even at exaggerated rates of application.

The studies discussed in this report were conducted with 2,4-D(2,4-dichlorophenoxyacetic acid), 2,4,5-T (2,4,5-trichlorophenoxyacetic acid), silvex (2-(2,4,5-trichlorophenoxy)propionic acid), and MCPA (2-methyl-2-chlorophenoxyacetic acid) in dairy and beef cattle and in sheep.

Anon. 1973. Health hazard of dioxins still uncertain. Chem. Engin. News. 51(16);12. (Report from a meeting involving more than 100 scientists from several countries).

Earlier this month, more than 100 scientists from several countries met at Research Triangle Park in North Carolina under the sponsorship of the National Institute of Environmental Health Sciences. They were there to discuss their work on the possible health and environmental hazards associated with chlorinated dibenzodioxins and chlorinated dibenzofurans. These compounds can be found as contaminants in the widely used chlorophenols and they have been linked to chick edema disease, which killed millions of broiler chickens in 1957. And in a study of 2,4,5-T herbicides widely used in Vietnam, they were found to cause a very high rate of birth defects in laboratory animals at very low dose levels.

The conference as a whole, however, seemed to raise as many questions as it answered. From the data discussed there is no doubt that these contaminants are highly toxic and teratogenic (causing birth defects). But there is still some doubt as to how much of an actual hazard they represent to human health.

The consensus of the gathering was that more work needs to be done. For instance, much of the research to date has been done only under controlled laboratory conditions and extrapolating such findings to the environment is hazardous at best. Also, no one has as yet determined how much of these contaminants is actually present in the ecosystem. Chlorophenols have a wide variety of uses. They can be found in herbicides, insecticides, fungicides, and as defoliants and antibacterial agents. Pentachlorophenol is widely used as a wood preservative.

Dr. James Wade of the University of Rochester pointed out to the conference that to be biologically active dibenzo-p-dioxin must have halogen substituents at the 2, 3, and 7 positions, with at least one hydrogen remaining on the nucleus. These findings were borne out by work done at Dow Chemical by Dr. B. A. Schwetz on the toxicology of these compounds, who reported that when chlorine is present at the 2 and 7 positions the compound is not biologically active as such. But it is lethal at very high dose rates. 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD) is highly embryotoxic, teratogenic, and acnegenic and is lethal in the microgram-per-kilogram of body weight range. The hexachloro compounds are also biologically active and lethal in milligram/kilogram doses. Octachloro compounds are embryotoxic and lethal in gram/kilogram doses.

Anon. 1973 (con't.)

It was brought out at the meeting that the effect of TCDD is unpredictable. It varies widely between species, within species, and between sexes. In rats receiving a single oral dose of 100 μg/kg, 6 of 14 died within an average of 18 days. However, a 3 μg/kg dose killed nine of 10 guinea pigs, while a 50 μg/kg dose had no apparent effect on mice. Multiple daily or weekly doses in much smaller quantities can also be lethal. The effect of dioxin seems to be cumulative up to a point when an irreversible process begins that results in death. Rats have died as long as 15 weeks after receiving a single oral dose of TCDD. Animals receiving daily or weekly doses, which were stopped after a period of time, have also died. Death in all animals seems to result from a general debilitation.

Laboratory studies on mice, rats, and guinea pigs at sublethal doses show that TCDD causes depressed weight gain, liver enlargement, and atrophy of the thymus. It is also embryotoxic and causes birth defects such as cleft palates and, in mice, badly retarded kidney development. In chickens the TCDD accumulates in tissues. Tissue from chickens with chick edema has been processed and fed to healthy chickens causing them to also become diseased.

Since herbicides are often sprayed from planes there is a chance that dioxins may find their way into streams and lakes. The U.S. Forest Service is studying the effect of dioxins on fish. In tests by Richard Miller, Coho salmon fingerlings were exposed for 24, 48 and 96 hours to water in which dioxin dissolved in dioxane had been added. At levels as low as 54 ng of TCDD, half the fish died within 50 days. The duration of exposure doesn't appear to affect survival time, however, the initial level of exposure does. Fingerlings treated at very low levels show a very marked lack of growth.

Dr. Robert Baughman of Harvard University told the conference that dioxin had been found in samples of fish collected in Vietnam in 1970. The highest concentration of contaminants is in fish from the Dong Nai River, an area that had been sprayed only lightly in the year before the fish were collected. TCDD in carp from this area runs from 500 to 800 ppt. Catfish and crayfish from the Saigon River had 7 to 200 ppt of TCDD, and shrimp from the coast had 20 to 80 ppt. In comparison a Cape Cod butterfish had only 3 ppt of dioxin. Dr. Baughman says the results raise the possibility of TCDD accumulation in food chains.

Anon. 1973 (con't.)

Some work has been done on how TCDD reacts with the environment. Dr. P. C. Kearney of the Department of Agriculture says that TCDD does not leach out of soil and therefore should not contaminate ground water. Soil tests show that after 1 yr 50% of the dioxin sprayed on a field remains. After 5 yr it has virtually disappeared. Chlorinated benzodioxins in solution can be photolytically degraded to lower, less toxic dioxin. However, a donor hydrogen must be present, therefore, it does not degrade on dry or moist soil. Some degradation does occur if the dioxin is in water.

Dr. Kearney also said that dioxins are not found in nature as a condensation product of chlorophenols. This agrees with work done by Dr. Horst Langer of Dow who found that while the sodium salts of chlorinated phenols can form dioxins at above 300° C., the herbicides in question do not form dioxin. Dr Langer said that if dioxin is not present in the herbicide as a contaminant, it won't arise in nature from any reaction.

U.S. makers of the herbicides and pesticides claim that the level of contaminants in their products is very low and poses no threat to human health. However, it remains to be seen whether the same can be said for products from foreign makers. At present the U.S. Air Force has the problem of disposing of more than 24 million pounds of herbicide left over from the war in Vietnam. In all probability most of this is contaminated and its disposal presents a problem that so far has not been solved.

Although most of the work discussed dealt with the dibenzodioxins there is every indication that the chlorinated dibenzofurans present very much the same kind of health hazard.

In California the sea lion population is experiencing a rising incidence of premature birth and death of pups. The concentrations of polychlorinated biphenyls in the sea lions is among the highest recorded in the environment and chlorinated dibenzofurans are found as contaminants in PCB.

Burt, D. W. and L. W. Storm. 1973. A teratological evaluation and LD_{50} for 2,4,5-T in the golden hamster. J. Ariz. Acad. Sci. 8(Suppl.):6. (Titles unknown, Univ. Las Vegas, Nevada; location where research conducted unknown).

The teratological potential and LD_{50} in the hamster, *Mesocricetus auratus*, was evaluated for the synthetic-phenoxy-herbicide, 2,4,5-T. The 2,4,5-T was suspended in a honey-water solution (1:1) and injected orally by the use of catheter tubing on days 6 to 10 of gestation. No terata were observed for dosages ranging from 75 to 175 mg/kg body weight as determined on day one of gestation. In the higher doses the health of the hamsters was severely affected and some resorptions were observed. Mean body weight of fetuses was also reduced as was the average litter size. The LD_{50} for deaths occurring within 72 hr was determined to be 425 mg/kg body weight.

Bjerke, E. L., J. L. Herman, P. W. Miller, and J. H. Wetters. 1973. Residue studies of phenoxy herbicides in milk and cream. Pestic. Abstr. 6(1):10. (J. Agr. Food Chem. 20:963-967, 1972). (Credentials unknown).

Cows fed a complete ration containing 2,4-dichlorophenoxyacetic acid, 2,4,5-trichlorophenoxyacetic acid, 2-(2,4,5-trichlorophenoxy)-propionic acid, or 2-methyl-4-chlorophenoxyacetic acid at six levels from 10 to 1000 ppm for 2 or 3 weeks at each level. Milk and cream samples were collected at predetermined intervals during the feeding of these chemicals and for seven days following withdrawal of the highest level. Residues of the acids and their phenol moieties were extracted with diethyl ether, separated by liquid chromatography on alumina, and determined as esters and phenols by electron capture or microcoulometric gas chromatography. The procedure was used to quantitate the chemicals down to 0.05 ppm with overall average recoveries of greater than 80%. The average residues found in milk at the highest feeding level were: 0.06 ppm, 2,4-dichlorophenoxyacetic acid; <0.05 ppm, 2,4-dichlorophenol; 0.42 ppm, 2,4,5-trichlorphenoxy-acetic acid; 0.23 ppm, 2,4,5-trichlorophenol; 0.12 ppm, silvex; <0.05 ppm, 2,4,5-trichlorophenol; <0.05 ppm, 2-methyl-4-chlorophenoxyacetic acid; 0.06 ppm, 2-methyl-4-chlorophenol. Residues of all chemicals decreased rapidly upon removal of the chemicals from the feed.

Fang, S. C., E. Fallin, M. L. Montgomery, and V. H. Freed. 1973. The metabolism and distribution of 2,4,5-trichlorophenoxyacetic acid in female rats. Toxicol. Appl. Pharmac. 24:555-563. (Titles unknown, Dep. Agriculture Chemistry, Oregon State University, Corvallis; research conducted at Oregon State University).

(1-^{14}C)-2,4,5-Trichlorophenoxyacetic acid (2,4,5-T) was fed to pregnant and nonpregnant female rats at various dosages and expired air, urine, feces, internal organs and tissues were analyzed for radioactivity. During the first 24 hr, 75 $\pm$ 7% of the radioactivity was excreted in the urine and 8.2 $\pm$ 4.6% in the feces. No ^{14}C was found in the expired air. There was no significant difference in the rate of elimination between the pregnant and nonpregnant rats, or among the dosages used. Radioactivity was detected in all tissues, with the highest concentration being found in the kidney. The maximum concentration of radioactivity in all tissues was generally reached between 6 to 12 hr after po dosing and then started to decline rapidly. Radioactivity was also detected in the fetuses and in the milk. The average biological half-life of 2,4,5-T in the organs was 3.4 hr for the adult rats and 97 hr for the newborn.

Kolberg, J., K. Helgeland, and J. Jonsen. 1973. Binding of 2,4-dichloro-2,4,5-Trichlorophenoxyacetic acid to bovine serum albumin. Acta Pharmacol. Toxicol. 33:470-475. (Titles unknown, Dep. Microbiology, University of Oslo, Oslo, Norway; research conducted in Norway).

The binding of 2,4-dichloro- and 2,4,5-trichlorophenoxyacetic acid (2,4-D and 2,4,5-T) to bovine serum albumin has been studied by a gel filtration technique (Hummel and Dreyer 1962). Both compounds were extensively bound to albumin, 2,4,5-T to a higher extent than 2,4-D. The binding of both herbicides was reduced when the protein contained palmitic acid.

Lloyd, J. W., J. A. Thomas, and M. G. Mawhinnery. 1973. 2,4,5-T and the metabolism of testosterone-1,2-$^{3}H_{2}$ by mouse prostate glands. Arch. Environ. Health 26:217-220. (Titles unknown, Dep. of Pharmacology and Dep. of Urology, West Virginia University Medical Center, Morgantown; research conducted at the Medical Center).

Lloyd et al. 1973 (con't.)

High doses of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) (6.25, 12.5, or 25 mg/kg ten times daily) were administered orally to mature male mice. The herbicide 2,4,5-T significantly reduced the assimilation of radioactive androgen by the prostate gland ($P<0.05$). This was reflected not only in a reduction in the total accumulation of testosterone-1, 2-$^3H_2$ (T-$^3H_2$) by the prostate gland, but also in a decrease in the levels of its labeled metabolites.

There was no change in the hepatic formation of either polar metabolites or of dihydrotestosterone, androstanediol, or androstenedione from T-$^3H_2$ in the 2,4,5-T treated mice. This pesticide had little or no effect on the weight responses of either the testes or the sex accessory organs. Prostate gland fructose, a chemical indicator of androgenic activity, was not altered by 2,4,5-T treatment.

Millard, S. A., M. B. Hart, and J. F. Shimek. 1973. Enzymes controlling cerebral DNA synthesis: response to 2,4,5-trichlorophenoxyacetic acid and hexachlorophene. Biochem. Biophys. Acta 308:230-233. (Titles unknown, Neurochemical Research Laboratory, University of Iowa College of Medicine, Iowa City; research conducted at the medical school).

2,4,5-Trichlorophenoxyacetic acid and hexachlorophene are potent inhibitors of ribonucleotide reductase from developing brain. The inhibition was partially reversed by Fe^{2+}. Administration of 2,4,5-trichlorophenoxyacetic acid to pregnant rates resulted in inhibition of fetal cerebral ribonucleotide reductase assayed *in vitro*. 2,4,5-trichlorophenoxyacetic acid did not inhibit cerebral DNA polymerase or thymidine kinase while 10^{-5} to 10^{-4} M hexachlorophene inhibited DNA polymerase.

Mullison, W. R. 1973. Herbicides are they safe? Down to Earth 29(3): 6-11. (Titles unknown, Dow Chemical, USA; summary article).

Piper, W. N., J. Q. Rose, M. L. Leng, and P. J. Gehring. 1973. The fate of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) following oral administration to rats and dogs. Toxicol. Appl. Pharmac. 26:339-351. (Titles unknown, Chemical Biology Research, The Dow Chemical Co., Midland, Mich.; research conducted in Midland).

Clearance of ^{14}C activity from the plasma and its elimination from the body of rats and dogs were determined after single oral doses of (carboxy-^{14}C) 2,4,5-T. The half-life values for the clearance of ^{14}C activity from the plasma of rats given doses of 5, 50, 100 or 200 mg/kg were 4.7, 4.2, 19.4 and 25.2 hr, respectively; half-lives for elimination from the body were 13.6, 13.1, 19.3 and 28.9 hr, respectively; half-lives for elimination from the body were 13.6, 13.1, 19.3 and 28.9 hr, respectively. The apparent volume of distribution also increased with dose. Urinary excretion of unchanged 2,4,5-T accounted for most of the ^{14}C activity eliminated from the body of rats. A small amount of unidentified metabolite was detected in the urine when rats were given 100 or 200 mg/kg but not 5 or 50 mg/kg. These results show that the distribution, metabolism and excretion of 2,4,5-T are markedly altered when large doses are administered.

In dogs given 5 mg/kg, the half-life values for clearance from plasma and elimination from the body were 77.0 and 86.6 hr, respectively, offering a plausible explanation of why 2,4,5-T is more toxic in dogs than in rats. Appreciable excretion in the feces was noted and three unidentified metabolites were detected in urine of dogs, indicating a considerable differences in metabolism of 2,4,5-T by dogs and rats given the same dose.

Smith, A. E. 1973. Influence of 2,4-D and 2,4,5-T on in vitro digestion of forage samples. J. Range Manage. 26:212-274. (Asst. Agronomist, Univ. Georgia, Experiment, Georgia; research conducted in Georgia).

The influence of 2,4-D ((2,4-dichlorophenoxy) acetic acid) and 2,4,5-T ((2,4,5-trichlorphenoxy) acetic acid) on in vitro digestion of dried ground corn silage (*Zea mays* L.) and bermudagrass (*Cynodon dactylon* L.) foliage was determined using a modification of the Tilley and Terry method for determining in vitro dry matter digestibility of forage plants. Neither herbicide influenced the digestion of plant samples when treated with a herbicide concentration range of 10^{-5} to 10^{-4} M. Solutions containing 10^{-4} M of either herbicide did not influence the growth of microbial populations in incubated rumen liquor. The influence of rumen microorganisms on degradations of 2,4-D and 2,4,5-T was also investigated. Samples containing sucrose or

Smith 1973 (con't.)

plant material, buffered rumen liquor, and 10^{-4} M concentrations of either herbicide were incubated for 10 day periods. Data from periodic quantification of herbicide remaining in the samples indicated that neither herbicide used in these experiments was degraded by the rumen microorganisms. Results indicate that: (1) 2,4-D and and 2,4,5-T do not alter the rumen microbial functions or development and (2) these herbicides are not readily degraded in the rumen by the rumen microorganisms.

Abo-Khatwa, N. and R. M. Hollingworth. 1974. Pesticidal chemicals affecting some energy-linked functions of rat liver mitochondria *in vitro*. Environ. Contam. Toxicol., Bull. 12:446-454. (Titles unknown, Dep. Entomology, Purdue Univ., West Lafayette, Indiana; research conducted at Purdue Univ.).

Berndt, W. O. and F. Koschier. 1974. In vitro uptake of 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) by renal cortical tissue of rabbits and rats. Pestic. Abstr. 7(4):257. (74-0951). (Toxicol. Appl. Pharmacol. 26:559-570, 1973). (Titles unknown, Dep. Pharmacology and Toxicology, Dartmouth Medical School, Hanover, N.H.; research conducted at Dartsmouth Medical School).

The active transport of 2,4-D and 2,4,5-T by renal cortical slices of rats and rabbits has been characaterized with in vitro techniques. Renal cortical slices, prepared from both species, accumulate 2,4-D and 2,4,5-T, although greater uptake was noted with rabbit tissue. Nitrogen and various metabolic inhibitors reduced the uptakes. This indicates that these processes are energy dependent. The enhancement of accumulation by the addition of certain metabolic substrates, e.g. acetate, lactate, provides evidence that both organic acid herbicides are transported by the renal organic anion mechanism. Potassium-ion stimulation also supports this concept. It is concluded that the renal tubular transport by the organic anion mechanism may account for the relatively rapid disappearance of these compounds, which in turn may contribute to their low toxicity.

Ford, D. H. 1974. Spike® for total vegetation control. Ann. Calif. Weed Conf., Proc. 26:25-27. (Plant Sci. Representative, Eli Lilly and Company, Fresno, Calif.; location of research unknown).

Based on the results from extensive research and experimental permit demonstration trials conducted throughout the United States, SPIKE® 80W has demonstrated the following advantages for total vegetation control on noncropland areas:

1. Controls a broader spectrum of herbaceous weeds and woody plants than currently available herbicides.

2. Provides long residual control.

3. Demonstrates good stability on soil surfaces.

4. Exhibits negligible lateral movement in soil.

5. Compatible with several other commercially available herbicides.

6. Relatively safe to humans, and poses no hazard to wildlife, birds, or fish.

Gribble, G. W. 1974. TCDD: a deadly molecule. Pestic. Abstr. 7(5):306. (74-1159). (Chemistry 47(2):15-18, 1974). (Title unknown, Dartmouth College, Hanover, N.H.; research conducted at Dartmouth College).

2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) is a chemically stable, water-insoluble white solid which melts at 300° C and begins to thermally decompose at 700° C. It is formed when pure 2,4,5-trichlorophenate is heated to 350 to 400° C. Other chlorinated dibenzo-p-dioxins (e.g., octachlorodibenzo-p-dioxin) can be formed in thermal reactions involving chlorinated phenols. TCDD is acnegenic, teratogenic, and lethally toxic, especially to guinea pigs. In laboratory animals it concentrates mainly in the liver, brain, and fatty tissues. Its oral administration to laboratory animals causes edema and hemorrhaging in the subcutaneous tissues, intestine, and brain ventricles, and general liver injury; death occurs 1 to 7 weeks after administration. Application of TCDD to the skin of laboratory rabbits and man causes chloracne, a severe skin disease. The biological activity of TCDD is almost unique to its particular arrangement of halogens; other chlorinated dibenzo-p-dioxins are much less active or inactive. In soil TCDD is not readily degraded, bio- or photosynthesized from 2,4,5-trichlorophenol, absorbed into plants, or mobile in the soil. Of 129 samples of 17 pesticides prepared from polychlorophenols and 20 samples of polychlorophenols, 76% contained from no TCDD to less than 0.1 ppm; only 9% contained more than 10 ppm TCDD. Research is needed to determine the effects of TCDD and related compounds on human health.

Hook, J. B., M. D. Bailie, J. T. Johnson, and P. J. Gehring. 1974. *In vitro* analysis of transport of 2,4,5-trichlorophenoxyacetic acid by rat and dog kidney. Food Cosmet. Toxicol, 12:209-217. (Titles unknown, Dep. of Pharmacology, Physiology, and Human Development, Mich. State Univ., East Lansing, Mich., and Chemical Biology Research, The Dow Chemical Co., Midland, Mich.; research conducted at Michigan State Univ.).

Renal transport of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) was studied quantitatively *in vitro* using renal cortical slices from dogs and rats, in an attempt to explain species differences in the biological half-life of the compound. Addition of 2,4,5-T to slices of rat renal cortex competively inhibited active transport of p-aminohippuric acid without altering transport of the organic cation, N-methylinicotinamide. Renal cortical slices from rats and dogs actively accumulated 2,4,5-T. Accumulation was oxygen dependent and saturable, and was reduced in the presence of other anions (p-aminohippurate and probenecid). A reduction in the potassium concentration of the medium reduced accumulation of 2,4,5-T by rat tissue but not by dog tissue. Acetate in the medium increased accumulation of the herbicide in dog but not in rat tissue. Finally, the ability of renal tissue from newborn rats to accumulate 2,4,5-T was significantly less than that of adult tissue. It is concluded that the primary route of renal elimination of 2,4,5-T is active secretion of the compound. The greater ability of adult rat tissue to transport PAH explains the shorter biological half-life of 2,4,5-T in this species.

Lindquist, N. G. 1974. An autoradiographic study on the distribution of the herbicide 4-chloro-2-methylphenoxyacetic acid in pregnant mice. Toxicol. Appl. Pharmac. 30:227-236. (Title unknown, Dep. Toxicology, University of Uppsala, Sweden; research conducted at the Univ. of Uppsala).

Whole body autoradiography was performed after varying intervals from 5 min up to 72 hr following iv injection of (^{14}C)4-chloro-2-methylphenoxyacetic acid (MCPA) in pregnant mice. The distribution pattern was characterized by a high concentration in the blood up to 4 hr, and an accumulation in the visceral yolk sac epithelium up to 24 hr after the injection. The radioactive substance passed the placenta, but the fetal tissues never reached the concentration of the maternal tissues.

Lindquist 1974 (con't.)

There was no site of accumulation in the fetal tissues. No retention occurred in either the maternal or the fetal tissues 48 hr after the injection. The distribution of (^{14}C)MCPA was observed to be similar to that found earlier for (^{14}C)2,4-dichlorophenoxyacetic acid (2,4-D) and (^{14}C)2,4,5-trichlorophenoxyacetic acid (2,4,5-T). The uptake, however, of (^{14}C)-MCPA and (^{14}C)2,4-D in the visceral yolk sac was weaker than that of (^{14}C)2,4,5-T. These results indicate a teratogenic mode of action for MCPA, similar to the one which has been postulated for 2,4,5-T (i.e., inhibition of the embryotrophic nutrition). It is also possible that a synergistic effect may occur between MCPA, 2,4-D, and 2,4,5-T with respect to their teratogenic action.

Maier-Bode, H. 1974. Residues and side-effects of herbicides in f rest protection. Health Aspects Pestic. 7(2):57. (74-0257). (Anz. Schaedlingsk. Pflanzen-Umweltschutz, 1973). (Title unknown, Pharmakol. Inst. Pheinische Friedrich-Wilhelms-Univ., Bonn, Germany; research conducted in western Germany).

Many of the herbicides currently authorized for use in forestry in West Germany cause problems with residues and possible side-effects. When applied as prescribed, these herbicides which include amitrole, chlorthiamid, dalapon, dichlobenil, paraquat, simazine, and 2,4,5-T are not harmful to terrestrial and aquatic flora and fauna, water quality, and wildlife. Damages to plants, aquatic organisms, and bees can be avoided by observing the directions for application. Dichlobenil, parathion, and sometimes DDT and chlorthiamid are harmful to bees; amitrole, dalapon, paraquat, simazine, and 2,4,5-T are not. Berries and mushrooms in treated forests usually contain residue levels too low to be harmful to humans. Groundwater contamination is negligible due to the low expenditure and the high absorption ability of forest soils and herbicides should not be applied near surface waters. Zero tolerance for amitrole residues in foods has been established. Very low residues and rapid elimination of chlorthiamid and dichlobenil were determined; and dalapon, 2,4,5-T, and paraquat were rapidly eliminated from humans and animals as well as from fruits.

Todd, G. C., W. R. Gipson, and C. C. Kehr. 1974. Oral toxicity of tebuthiuron (1-(5-<u>tert</u>-butyl-1,3,4-thiadiazol-2-yl)-1,3-dimethylurea) in experimental animals. Food Cosmet. Toxicol. 12:461-470. (Titles unknown, Toxicology Div., Lilly Research Lab., Greenfield, Ind.; research conducted in Greenfield).

Todd et al 1974 (con't.)

The toxicity of tebuthiuron (1-(5-tert-butyl-1,3,4-thiadiazol-2-yl)-1,3-dimethylurea) has been studied in several aminal species. The acute oral LD_{50}s in mice, rats and rabbits were 579, 644, and 286 mg/kg, respectively. In cats, oral doses of 200 mg/kg were not lethal while 500 mg/kg given orally did not kill dogs, quail, ducks or chickens. The acute TL_{50} in fish was >160 ppm.

A 3-month study in rats fed diets containing 0, 400, 1000 or 2500 ppm tebuthiuron resulted in moderate growth retardation and a reduction in the efficiency of food utilization in the highest dose group. These changes were evident by week 1 of the study. In the same group, a non-inflammatory diffuse vacuolization of the pancreatic acinar cells was found. No other important evidence of toxicity occurred. A 3-month study in dogs given daily oral doses of 0, 12·5, 25 or 50 mg tebuthiuron/kg resulted in slight anorexia in all the treated dogs, and a slight body-weight loss in dogs of the highest dose group. There were no other treatment-related signs of toxicity. A 1-month study in chickens fed rations containing 0, 400, 1000 or 2500 ppm tebuthiuron produced, in the highest treatment group, a reduction in food intake and suppression of body-weight gain but no other signs of toxicity. A teratology study produced no significant effects in the offspring of rats fed diets containing 0, 600, 1200 or 1800 ppm tebuthiuron.

Skin and eye irritation studies in rabbits and a contact sensitization study in guinea-pigs revealed no remarkable evidence of toxicity.

These studies indicate that tebuthiuron has a low order of toxicity in animals.

Anon. 1975. TCDD - a potent inducer. Drug Metabolism and Disposition

3(4):322. (Credentials unknown).

Within the past 2 years a number of reports have been published on the effects of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) on drug-metabolizing enzyme systems. This material is a contaminant in chlorinated fungicides, herbicides, and polychlorinated biphenyls, and is quite toxic. It soon became evident that TCDD is the most potent (although somewhat selective) inducer of drug-metabolizing enzyme systems that has yet been described. Fewer molecules of this compound must be administered to an animal to elicit induction of hepatic microsomal drug-metabolizing enzymes than there are of cytochrome P-450 in the liver. An oral dose of 1 μg/kg causes a significant increase in "cytochrome P-450" levels in the liver of male rats (with shift of maximal wavelength of the reduced CO-complex to 448 nm), and one-fifth of this amount causes a significant induction in the female rat. At these levels, benzpyrene hydroxylase activity is also induced. Other microsomal activities induced at low levels of TCDD are those of biphenyl 2- and 4-hydroxylase, aniline hydroxylase, zoxazolamine hydrolase, and UDP-glucuronyltransferase. Zoxazolamine

Anon 1975 (con't.)

paralysis time is greatly shortened after pretreatment with TCDD. However, hexobarbital sleeping time is greatly increased after such pretreatment, and the rate of microsomal metabolism of hexobarbital is greatly reduced. Demethylase activities toward benzphetamine, aminopyrine, and ethylmorphine are also greatly reduced in liver microsomes of rats treated with this toxicant.

The inductive effects of TCDD are quite persistent in rat liver microsomes; significant induction of benzpyrene hydroxylase may still be observed 73 days after a single oral dose of the compound. The suppression of N-demethylase activities, however, lasts for a shorter time, and is no longer seen 35 days after treatment. Whereas the stimulating effect on hydroxylase activities may be observed in rats of all ages, the suppressive effect on N-demethylase is age-dependent; thus, TCDD stimulates N-demethylation in 10-day-old rats, but suppresses this activity in rats after weaning. The effects of the toxicant upon constituents of smooth and rough endoplasmic reticulum varies. Thus, hydroxylase and glucuronyltransferase activities are stimulated in both SER and RER, whereas demethylase activities are suppressed only in the SER. Phospholipid concentration in decreased in the SER, but increased in the RER. Changes in drug-metabolizing enzyme activities also occur in extrahepatic tissue; there is a great deal of substrate, organ, and species specificity.

The potency, specificity, and persistence of effects of TCDD upon drug-metabolizing enzyme systems offer great promise that this compound will prove to be a quite valuable tool in the study of the mechanisms of regulation of drug metabolism.

Bartleson, F. D., Jr., D. D. Harrison, and J. D. Morgan. 1975. Wildlife (mammals) observations on TA C-52A, p. 29. In, Field studies of wildlife exposed to TCDD contaminated soils. Final report ending February, 1975. Air Force Armament Laboratory. (Eglin Air Force Base, Florida). (Lt. Col., unknown title and 1st Lt. (USAF), respectively; research conducted at Eglin Air Force Base).

A study was made of the birds, other wildlife, and soils in two areas of the Eglin Air Force Base Reservation, Florida, which previously had been exposed to massive quantities of military herbicides containing the highly toxic chemical 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). The studies were conducted on a 3 mi^2 test site (Test Area C-52A) where aerial dissemination equipment was tested and around a hardstand where the spray-aircraft were loaded. TCDD was found to be persistent and widespread in these areas. No positive deleterious effects from the TCDD were found. Evidence was found, however to

Bartleson et al. 1975 (con't.)

suggest that selected species of wildlife, in restricted habitats, might have been affected. TCDD had entered certain food chains, and bioaccumulation was demonstrated. Transient wildlife and certain herbivorous animals appeared to suffer no ill effects. Recommendations were made for a method to accelerate degradation of TCDD in terrestrial environments and for specific follow-up studies on TCDD wildlife effects.

Clark, D. E., J. S. Palmer, R. D. Radeleff, H. R. Crookshank, and F. M. Farr. 1975. Residues of chlorophenoxy acid herbicides and their phenolic metabolites in tissue of sheep and cattle. Pestic. Abstr. 8(8):536 (75-1957). (J. Agr. Food Chem. 23:573-578, 1975). (Titles unknown, USDA-ARS, College Station, Texas).

Three chlorophenoxy acid herbicides, 2,4-D, 2,4,5-T, and silvex, were fed at four dosage levels (0, 300, 1000, and 2000 ppm) to adult sheep and cattle for 28 days. Some were killed and tissues were sampled 1 day after the last dose, other 1 week later. Residues of the chlorophenoxy acid herbicides and their phenol metabolites were determined in muscle, fat, liver, and kidney. Analytical methods for determining tissue residues of chlorophenoxy acids and chlorophenols are presented. Muscle and fat contained the least residues of the herbicides or their metabolites. Kidneys contained the highest residues of each of the three herbicides. Liver and kidney contained the highest levels of either 2,4,5-dichlorophenol or 2,4,5-trichlorophenol. Withdrawal from treatment for 1 week before killing resulted in significant reduction in tissue residue levels. No species difference in regard to chlorophenoxy herbicide residue deposition was observed. Anorexia, either partial or complete, accompanied by decreased weight gains was observed, especially at the highest dosage levels.

Dougherty, W. J., M. Herbst, and F. Coulston. 1975. The non-teratogenicity of 2,4,5-trichlorophenoxyacetic acid in the rhesus monkey (*Macaca mulatta*). Environ. Contam. and Toxicol. 13:477-482. (Titles unknown, Internat. Center of Environ. Saftey, Albany Medical College, Holloman AFB, N.M., Dep. Exp. Pathology and Toxicology, Germany, and Inst. Comparative and Human Toxicology, Albany Medical College, Albany, N.Y., respectively; research conducted at Holloman AFB).

Dougherty et al. 1975 (con't.)

The herbicide 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) containing 0.05 ppm of tetrachlorodibenzo-p-dioxin, was administered to pregnant rhesus monkeys daily from Day 22 through Day 38 of gestation. At the dose levels administered, 0.05 mg/kg, 1 mg/kg, and 10 mg/kg, no evidence of toxicity was seen in the mother and no evidence of teratogenicity was seen in any of the offspring. Observations of the infants for 1 year following birth indicated that there was no toxicity due to the 2,4,5-T.

Dragsnes, L., K. Helgeland, and J. Jonsen. 1975. Effects of the herbicide 2,4,5-trichlorophenoxyacetic acid or growth and morphology of L 929 cells. Acta Pharmacol. Toxicol. 36:97-102. (Titles unknown, Dep. Microbiology, Univ. of Oslo, Norway; research conducted at the Univ. of Oslo).

A dose-dependent inhibition of growth was found when monolayer cultures of L 929 cells were grown in the presence of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) in concentrations from 0.25 to 2.25 mM. At 1.75 and 2.25 mM an almost immediate cessation of growth was found. On removal of the herbicide (2.25 mM) after incubation for 3 or 6 days, cell multiplication was resumed after a lag period of about 24 hours. In the presence of 0.5 to 2.25 mM 2,4,5-T an accumulation of particles in the cytoplasm was observed, and on prolonged incubation in the presence of 2.25 mM 2,4,5-T the cells became rounded and detached from the substratum. By replacing the test medium by the control medium, however, the particles in the cytoplasm disappeared and the cells resumed their fibroblast-like structure.

Thalken, C. E., W. E. Ward, and A. L. Young. 1975a. Absense of TCDD toxicity to a rodent population following massive field application of 2,4,5-T herbicide. One Hundred Twelveth Annual Am. Vet. Med. Assoc., Abstr. No. 81. Anaheim, Calif. 1p. (DVM, Ph.D., and Ph.D., respectively, U.S. Air Force Academy, Colorado; location where research conducted unknown).

Thalken et al., 1975a (con't.)

Field investigations were conducted on populations of beach mice, *Peromyscus polionotus*, and hispid cotton rats, *Sigmodon hispidus* from a unique 1-sq. mile military test site that was sprayed with 160,948 lb a.i. 2,4,5-trichlorophenoxyacetic acid herbicide (2,4,5-T). Significant levels (10 to 710 parts per trillion - ppt) of the contaminant 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) were found within the top 6 inches of test site soils although 10 years had elapsed since the last aerial application of 2,4,5-T. Liver tissue from rodents inhabiting the test site contained 210 to 1,300 ppt TCDD. However, no gross or histological evidence of teratogenesis or toxicity was found in 122 adults and 87 fetuses. An analysis of variance of liver and spleen weights for the beach mouse indicated significant differences between control and TCDD-exposed animals. Analysis of plant seeds revealed no detectable levels of TCDD (minimum detection limit of 1 ppt TCDD). TCDD accumulation in liver tissue was thought to be associated with pelt contamination from burrowing and subsequent ingestion of soil particles via grooming.

Young, A. L., C. E. Thalken, and W. E. Ward. 1975b. Vegetative assessment of test area C-52A, p. 11-27. In, Studies of the ecological impact of repetitive aerial applications of herbicides on the ecosystem of test area C-52A, Eglin AFB, Florida. Final Report ending December, 1974. AFAIL-TR-75-142 (Air Force Armament Laboratory. Eglin Air Force Base, Florida). (Captain (Ph.D.), Major (V.C.), and Lt. Col. (Ph.D.) of USAF, respectively; study area Eglin AFB, Florida).

In 1962, the Armament Development and Test Center, Eglin Air Force Base, Florida, was tasked with the responsibility for designing, developing, and testing aerial dissemination systems in support of military defoliation operations in Southeast Asia. It was necessary for this equipment to be tested under controlled conditions that were as near to being realistic as possible. For this purpose an elaborate testing installation, designed to measure deposition parameters, was established on the Eglin Reservation with the place of direct aerial application restricted to a highly instrumented area within Test Area C-52A (TA C-52A) in the southeastern part of the Reservation.

Young et al., 1975b (con't.)

A total of 346,117 pounds of herbicides were applied through repetitive aerial applications, over a period of 8 years (1962-1970), to an area of approximately 1 m^2. The active ingredients of the four military herbicides (Orange, Purple, White, and Blue) sprayed on TA C-52A were 2,4-dichlorophenoxyacetic acid (2,4-D), 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), 4-amino-3,5,6-trichloropicolinic acid (picloram), and dimethylarsinic acid (cacodylic acid). It was apparent from analysis of remaining Orange herbicide samples and test grid soils that the 2,4,5-T herbicide contained significant levels of the highly teratogenic (fetus deforming) contaminant 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). In particular, one 92-acre test grid (Grid 1) used from 1962 through 1964 received 87,186 lb of 2,4,5-T. In 1974, analysis of 6-inch soil cores for TCDD, taken at six locations in this area, indicated wide fluctuations in TCDD concentrations. The results for the uniformily mixed top 6-inch soil cores were 10, 25, 70, 110 and 710 parts per trillion (ppt) TCDD. Further analysis of a duplicate core, obtained from the site having 110 ppt TCDD concentration indicated that TCDD was stratified within the top 6 inches of soil. The analysis for depths of 0 to 1, 1 to 2, 2 to 4, and 4 to 6 inches resulted in detectable levels of 150, 160, 700 and 44 ppt TCDD, respectively. Thus significant levels of TCDD residue were found 10 years after the last herbicide mission on this grid.

This report documents the quantitative changes that have occurred in the vegetative and insect communities with ecological succession. In addition, detailed chemical and histopathological studies of segments of the rodent and reptile populations from the test site containing significant levels of TCDD in soil (Grid 1) are reported. Species diversity and food chain studies of the aquatic ecosystems associated with TA C-52A are evaluated.

Because of the massive quantities of herbicides applied to TA C-52A, a unique opportunity existed to evaluate changes in vegetative patterns and/or succession. Field data suggested that climatic factors rather than herbicide residue influenced vegetative establishment especially on the southern portion of the test area, e.g., on or near Grid 1. When wind and temperature data, collected from 1963 to 1969, were combined with data on seed dispersal and regeneration potential, it became apparent that unfavorable conditions on the southern portion of the test area existed at the time when seed dispersal and establishment occurred. Nevertheless, when establishment did take place, a definite sequence in plant succession could be documented. The large seed grasses *Panicum virgatum*, switchgrass, and *Panicum lanuginosum*, woolly panicum, were the first perennial species to assume dominance. The annual herbs *Diodia teres*, rough buttonweed, and *Hypericum gentianoides*, poverty weed, rapidly spread in the loose soil around and between the dominant grasses. With time, other grasses occupied significant vegetative cover, especially *Andropogon virginicus*, broomsedge and *Eragrostis refracta*, coastal lovegrass. The square foot transect

Young et al. 1975b (con't.)

method of analysis indicated that areas having 5 to 20 % vegetative cover generally contained 14 species (8 grasses, 6 herbs) while an area of 80 to 100 % vegetative cover generally contained 28 species (8 grasses, 20 herbs). Similarity between seeds most frequently found in rodent burrows and those from species shown to be early dominants in the plant community suggested that rodents may act as biological dispersal agents into areas of low vegetative cover.

Extensive animal studies were conducted during the summer of 1974. Several methods and procedures were used for collecting data on six interrelated parameters. These included extensive histopathologic examination of beach mouse (*Peromyscus polionotus*) tissues, a study of beach mouse burrow construction and diet, TCDD analysis of mouse liver tissue and pelts, an examination of the soil profile for potential zoning of TCDD, a laboratory experiment to demonstrate one possible route of TCDD uptake by the beach mouse, and an analysis of reptile tissue for TCDD contamination.

A total of 106 adult and 67 fetuses of beach mice were examined grossly and histologically for congenital and teratogenic defects. In general, microscopic examination of all tissues showed only minor and insignificant lesions of the type normally observed when a large group of animals are examined. The only exceptions being two mice with necrotizing hepatitis and one mouse with renal ectasia of one kidney. The hepatitis was considered to be viral induced and the renal ectasia was interpreted as being of little functional significance and probably a result of a unilateral congenital anomaly not related to any toxicity. An analysis of variance of liver and spleen weights indicated significant differences between control and TCDD-exposed animals. However, these differences were not explained by any histologic differences.

Samples of liver and pelts from mice captured in areas in which significant soil levels of TCDD were found, exhibited accumulations of TCDD in the liver from 540 to 1300 ppt, while pelt contamination was found to be 130 to 140 ppt.

A study of the beach mouse burrows and diet, combined with the findings that TCDD was confined to the top 6 inches of soil, suggested that a possible method of exposure to TCDD might be through soil contamination of the pelt during burrowing and movement of the animal through these burrows followed by subsequent ingestion of soil particles through grooming. The beach mouse was observed in the laboratory to spend much of its active period grooming. Thus, a laboratory study was conducted using alumina gel with and without 2.5 ppb TCDD to dust the pelts of test and control mice. This study confirmed 45 to 89 ppt were found on the pelts and a level of 125 ppt was found in liver tissues.

Young et al. 1975b (con't.)

The racerunner, *Cnemidophorus sexlineatus*, the most prevalent reptile on the grid, was also trapped and examined for gross defects as well as having tissue samples analyzed for TCDD residue. Significant levels of TCDD were found in the visceral mass (360 ppt) and the trunk (370 ppt) of reptiles collected from areas where soil levels of TCDD were the highest (Grid 1). These reptiles, however, showed no significant lesions or variations in visceral mass between control specimens and those collected from the contaminated sites.

A 1973 sweep net survey of the arthropods of the 1 mi^2 area resulted in the collection of 5966 specimens belonging to 71 insect families and two arachnid orders. These totals represent the collections from five paired sweeps taken over a 1-mile section of the test grid. A similar study performed in 1971 produced 1796 specimens, representing 70 insect families and one arachnid order, from five paired sweeps of the same area using the same basic sampling techniques. A much greater number of small to minute insects were taken in the 1973 study. Vegetative coverage of the test area had significantly increased since the 1971 study. Comparison of the results of the two studies also showed significant increases in the number of arthropod specimens and varieties per sampled grid transect, but there was little overall change in calculated community diversity. These results are not unexpected, and the population increases will continue as the test area stabilizes and develops further plant cover, thus allowing a succession of animal populations to invade the recovering habitat.

Species diversity studies were conducted in two aquatic ecosystems associated with TA C-52A (Trout and Mullet Creeks), while food chain studies were conducted only in one stream (Trout Creek) and a grid pond. Both the latter two locations were shown in 1973 to contain TCDD in silt. Since TCDD was not water soluble, a different route of entry into these aquatic systems was sought. Examination revealed that erosion of soil occurred into the pond on the test area and into the bayhead of Trout Creek immediately adjacent to Grid 1. TCDD levels of 10 to 35 ppt were found in silt of the aquatic systems, but only at the point where eroded soil entered the water. Species diversity studies of the stream were conducted in 1969, 1970, 1973, and 1974. Insect larvae, snails, diving beetles, crayfish, tadpoles, and major fish species from both aquatic systems were analyzed for TCDD. Species diversity studies indicated no significant change in the composition of ichthyofauna between these dates or a control stream. Concentrations of TCDD (12 ppt) were found in only two species of fish from the stream, *Hotropis hypselopterus*, sailfin shiner, and *Gambusia affinis*, mosquitofish. The sample of mosquitofish consisted of bodies with heads and tails removed. The samples of sailfin shiners were analyzed; on containing viscera only and the other bodies less heads, viscera, and caudal fins. Only the viscera contained TCDD. Samples of skin, muscle, gonads, and gut were obtained from *Lepomis punctatus*, spotted sunfish, from the test grid pond. Levels of TCDD in those body parts were 4, 4, 18, and 85 ppt, respectively. Gross pathological observations of the sunfish revealed no significant lesions or abnormalities.

Highman, B., T. B. Gaines, and H. J. Schumacher. 1976a. Sequential histopathologic, hematologic, and blood chemistry changes induced by a technical and purified preparation of 2,4,5-trichlorophenoxyacetic acid. J. Toxicol. Environ. Health 1:469-484. (Titles unknown, Dep. Pathology, Univ. Arkansas Medical Center, Little Rock, and Div. Teratology, National Center for Toxicological Research, Jefferson, Ark.; research conducted at the National Center for Toxicological Research).

Maternal mice were given 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) on days 6 through 14 of pregnancy in a teratologic study at the National Center for Toxicological Research. Sick or moribund mice sacrificed after 4 to 8 doses of 120 mg/kg 2,4,5-T often showed severe myocardial lesions, hypocellularity of the bone marrow, and depletion of lymphocytes in the thymus, spleen, or lymph nodes. Healthy mice sacrificed on day 17, 11 days after treatment began, showed few or no severe lesions. To determine if lesions earlier in gestation contributed significantly to an increase in fetal abnormalities in the healthy 17 day survivors, dihybrid cross F_2 pregnant and nonpregnant mice received by gavage 0, 60, or 120 mg/kg 2,4,5-T on days 6 through 14 of pregnancy. One group received a technical preparation containing 97.9 $\pm$ 0.4% 2,4,5-T; another received a purified preparation containing 99 $\pm$ 0.3% 2,4,5-T. Mice were sacrificed when they became moribund and at 6, 24, and 30 hr, as well as at 4, 6, 8, and 11 days after beginning treatment. Almost all mice given 60 mg/kg and many given 120 mg/kg 2,4,5-T appeared normal at sacrifice either early or late in pregnancy and showed little or no pathologic changes. Mice that became ill or moribund often showed severe lesions; few survived 11 days. Severe myocardial lesions were seen in 26 of 70 moribund mice given the technical 2,4,5-T and 24 of 33 given the purified preparation of 2,4,5-T. The moribund mice, particularly those given the purified compound, also showed a high incidence of lesions in other organs and marked hematological and blood chemistry changes. These findings indicate that the lesions are primarily due to 2,4,5-T rather than to impurities in the technical preparation.

Highman et al. 1976 (con't.)

treatment. Sick or moribund mice sacrificed after 2 to 9 doses of 2,4,5-T often showed severe myocardial lesions, hypocellularity of the bone marrow, and depletion of lymphocytes in the thymus, spleen, or lymph nodes. They also showed marked hematologic and blood chemistry changes. Treated mice remaining healthy showed few or no lesions or blood chemistry changes, but often developed a mild anemia attributable to a hemolytic effect of 2,4,5-T. The incidence of animals becoming moribund was less than 1% in the CD-1 mice, including those given 140 mg/kg, and 53 to 82% in groups of male and female F_2 mice receiving 120 mg/kg 2,4,5-T. The incidence of moribund mice tended to be higher in male than in female F_2 mice and in those given the purified compound. These findings indicate that impairment of maternal health by severe lesions early in gestation is not the primary cause of an increase in incidence of fetal abnormalities observed in mice given 2,4,5-T. They also indicate that the lesions are due primarily to 2,4,5-T, rather than contaminants in the technical preparation, and illustrate the importance of using more than one strain of mouse in a toxicologic or teratologic study.

Highman, B., T. B. Gaines, H. J. Schumacher, and T. J. Haley. 1976b.

Strain differences in histopathologic, hematologic, and blood chemistry changes induced in mice by a technical and a purified preparation of 2,4,5-trichlorophenoxyacetic acid. J. Toxicol. Environ. Health. 1:1041-1054. (Titles unknown, Dep. Pathology, Univ. Arkansas Medical Center, Little Rock, and Div. Teratology, National Center for Toxicological Research, Jefferson, Ark.; research conducted at the National Center for Toxicological Research).

Including controls, 978 mice were studied. On days corresponding to days 6 through 14 of pregnancy, groups of pregnant and nonpregnant CD-1 mice and male and nonpregnant female dihybrid cross F_2 mice received by gavage 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) ranging in dosage from 30 to 140 mg/kg. Some groups received a technical preparation containing 97.9 $\pm$ 0.4% 2,4,5-T and some a purified preparation containing 99 $\pm$ 0.3% 2,4,5-T. Mice were sacrificed when they became moribund and at 1, 2, 4, 6, 8, and 11 days after beginning

Hook, J. B., R. Cardona, J. L. Osborn, M. D. Bailie and P. J. Gehring. 1976. The renal handling of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) in the dog. Food Cosmet. Toxicol. 14:19-23. (Titles unknown, Dep. of Pharmacology, Physiology, and Human Development, Mich. State Univ., East Lansing, Mich., and Chemical Biology Research, The Dow Chemical Co., Midland, Mich.; research conducted at Michigan State Univ.).

The herbicide 2,4,5-T is actively transported by renal cortical slices of dogs and rats, suggesting that the compound should be rapidly eliminated from the body via the kidneys. The prolonged plasma half-life of 2,4,5-T in the dog (77 hr) indicates that factors other than secretion into the urine are important determinants of elimination in the dog. This study was designed to determine the renal handling of 2,4,5-T in anaesthetized dogs, and an attempt was made to increase excretion of the herbicide with sodium acetate. Injection of 2,4,5-T decreased clearance of p-aminohippurate in a dose-dependent manner, suggesting that the compound was actively secreted. The clearance of the herbicide however, was exceedingly low, being less than 1% of inulin clearance. The clearance of 2,4,5-T was increased by sodium acetate and by acetazolamide. Additional studies with mannitol, sodium bicarbonate and ammonium chloride demonstrated that clearance of 2,4,5-T was related to urinary pH, but only when the pH exceeded 6, and was not affected by changes in urine volume. Addition of plasma inhibited the transport of 2,4,5-T by renal cortex slices *in vitro*, suggesting that the low clearance *in vivo* was due to a very tight binding of the herbicide to plasma protein.

Morton, D. M. and D. G. Hoffman. 1976. Metabolism of a new herbicide, tebuthiuron (1-(5-(1,1-dimethylethyl)-1,3,4-thiadiazole-2-yl)-1,3-dimethylurea), in mouse, rat, rabbit, dog, duck, and fish. J. Toxicol. Environ. Health 1:757-768. (Titles unknown, Toxicology Div., Lilly Research Labs., Greenfield, Indiana; research conducted at Greenfield).

Morton and Hoffman 1976 (con't.)

Orally dosed tebuthiuron was readily absorbed in mice, rats, rabbits, dogs, and ducks. The compound was extensively metabolized and the metabolites were rapidly excreted in the urine of mice, rats, rabbits, and dogs and in the mixture of urine and feces in ducks. The major metabolites of tebuthiuron were formed by N-demethylation of the substituted urea side chain in each species examined, including fish. Oxidation of the dimethylethyl group occurred in mice, rats, dogs, rabbits, and ducks. The N-demethylation reaction at the 3-position of the urea proceeded through an N-hydroxymethyl intermediate. No accumulation of tebuthiuron or its metabolites was observed in the animals, a finding consistent with the low order of toxicity observed in other studies.

Newton, M. and L. A. Norris. 1976. Evaluating short- and long-term effects of herbicides on nontarget forest and range biota. Down to Earth 32(3):18-26. (Prof. of Forest Ecology, Oregon State Univ., and Supervisory Research Chemist, USDA-FS, Corvallis, Oregon; summary article).

It is beyond the scope of our paper to present extensive quantitative data. In general, however, these authors indicate that for a 1 kg/ha application, initial herbicide residue levels would (1) generally be less than 100 ppm in vegetation, (2) be less than 3 ppm in the surface 2.5 cm of soil and (3) be less than 0.05 ppm in streams unless extensive direct application is made to surface water. These initial residue levels will vary somewhat with conditions of application and vegetation composition and density. They are quantities that produce effects on sensitive plant species, but not animals exposed to the same applications. Animal exposure occurs dermally during and immediately after application. Dermal toxicity of herbicides is typically low enough to be of only academic importance, as attested by research data and years of actuarial data for sprayment exposed daily to the concentrates.

Oral ingestion, however, may be significant. Given the maximum level of 100 ppm in treated herbage, an animal consuming five percent of its weight per day ingests a maximum 5 mg/kg/day for each kg/ha applied, assuming all of its feed has a maximum concentration of herbicide. Animals appear to take in less than the maximum, however. Newton and Norris (1968) reported intake of atrazine and 2,4,5-T by deer amounting to about 1% of the theoretical maximum, or less. Furthermore, deterioration of both the herbicide and the treated vegetation limits exposure to a relatively short period, and herbicides usually pass through the digestive system with little or no retention or accumulation.

Newton and Norris 1976 (con't.)

Herbicide movement and persistence are difficult to generalize in reference to precise levels of exposure to consumer and aquatic organisms. Norris (1971) and House et al. (1967) again offer reasonable summaries for persistence characteristics in vegetation and water. In vegetation, herbicide half-lives range from 1 to 30 days; the half-life in stream water ranges from less than 0.5 to 24 hr in water when herbicide input is restricted to the time of application. Rapid herbicide dilution with downstream movement tends to protect aquatic organisms, and the recurrence of contamination by movement of soil water is unlikely (Norris and Moore, 1970). Kearney et al. (1969) and Harris (1968) report in detail on the mobility and persistence of herbicides in soil.

The data on residue and persistence characteristics of an herbicide in a specific environment can be used to determine both the magnitude and duration of nontarget organism exposure. Exposure data can then be evaluated in terms of established dose-response relationships for the chemical and the specific organism or a closely related species for which test data are available. If the magnitude and duration of exposure are less than the threshold response level, direct toxic effects are precluded. This kind of an analysis consistently shows those herbicides and patterns of use registered by the Environmental Protection Agency for use on forest and rangelands will not normally result in direct toxic effects on nontarget animals. Moreover, evidence is strong that there is a rather large margin of safety in this regard even in the event of accident or other mishap.

Young, A. L., C. E. Thalken, E. L. Arnold, J. M. Cupello, and L. G. Cockerham. 1976. Fate of TCDD in an ecosystem (rodent studies), p. 23-27. In, Fate of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) in the environment: summary and decontamination recommendations. USAFA-TR-76-18. (Capt. (Ph.D.), Major (DVM), Lt. Col. (Ph.D.), Capt. (Ph.D.), and Major M.S.), respectively, Dep. Chemistry and Biological Sciences, USAF Academy, Colorado; research conducted at Eglin AFB, Florida, Garden City, Kansas, and Air Force Logistics Command Test Range Complex, Utah).

Young et al. 1976 (con't.)

Studies on the fate of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) have been conducted on biodegradation plots and field test areas that have received massive quantities of Orange herbicide (a 50:50 mixture of the n-butyl esters of 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). From the studies reviewed in this report, it is apparent that (1) although TCDD may persist in the environment for long periods of time (greater than 12 years) when initially present at high concentrations on the soil surface, it may be degraded by soil microorganisms, especially when in the presence of other chlorinated hydrocarbons (an estimated half-life for TCDD in the presence of 2,4-D and 2,4,5-T herbicides is 225 days); (2) TCDD may accumulate in the tissues of rodents, reptiles, birds, fish, and insects when these organisms are exposed to TCDD contaminated soils (however, the levels of TCDD in the tissues apparently do not exceed the levels of TCDD found in the environment); (3) rodents, reptiles, birds, fish and insects may tolerate, i.e., based on no observed deleterious effects in field studies, soil levels between 10 and 1,500 ppt TCDD; (4) TCDD may be degraded in the presence of sunlight; (5) movement of TCDD in the abiotic portions of the environment can be by wind or water erosion of soil particles, but leaching by water alone does not appear to occur; and (6) TCDD is probably not readily released or degraded in the environment when bound to activated coconut charcoal.

Frohberg, H., J. Gleich, and A. Hoffman. 1977. Investigations on the embryotoxic effect of 2,4,5-T in NMRI mice. Teratology 10:309. (Titles unknown, Inst. Toxicology, Darmstadt, F.R.G.; location where research conducted unknown).

The herbicide 2,4,5-T was given as free acid =(A) (dioxin content <0.1 ppm) in arachis oil and as butoxyethylester (Hormoslyr 500 T(R)= (E) to NMRI-EMD-SPF mice from the sixth and fifteenth day p.c. in oral doses of 0, 20, 40, and 120 mg/kg/day. The mice were also exposed to inhalable aerosol generated from diluted E in concentrations of 392 mg/m^3 and 406 mg/m3 from days 6 to 10 p.c. and 11 to 15 p.c. respectively. Doses and concentrations are expressed as free acid.

Frohberg et al. 1977 (con't.)

After 10 oral applications of 80 and 120 mg/kg (toxic for mother animals) malformations (7.9 and 22.4% resp.) and fetal loss (FL) (13.5 and 51.5% resp.) were observed. E. affected fetal development only in the highest dose. The malformation rate (MR) was 11.6% and that of FL 11.6%. In the inhalation experiments with 216 mg/m^3 E showed a slight maternal toxic, fetotoxic (FL=11.6%) and teratogenic (MR=22.2%) effect. After 10 exposures to 374 mg/m^3 5 of 15 dams died. Exposure to 392 mg E/m^3 (day 11-15 p.c.) was toxic for adults and fetolethal (FL 58.5% and 28.1% resp.). After inhalation from day 11 to 15 p.c. the MR was 30.9%. These results do not substantiate a special risk to the human embryo from regular use of 2,4,5-T.

Council for Agricultural Science and Technology. 1978. The phenoxy herbicides. Report No. 77. Iowa State Univer., Ames. 28p. (Credentials unknown).

The phenoxy herbicides, 2,4-D, 2,4,5-T, MCPA, silvex and related materials, are selective herbicides widely used in crop production and in the management of forests, ranges and industrial, urban and aquatic sites. These chemicals are related to naturally occurring plant growth regulators. They kill plants by causing malfunctions in growth processes. Broad-leaved plants are generally susceptible to the phenoxy herbicides, whereas most grasses, coniferous trees and certain legumes are relatively resistant.

The phenoxy herbicides are used to control broad-leaved weeds in wheat, barley, rice, oats, rye, corn, grain sorghums and certain legumes. Such uses increase yields, improve product quality and reduce production costs. The phenoxy herbicides are used in forests to suppress unwanted hardwood trees and brush, to reduce competition with conifers already established or to prepare sites for the regeneration of conifers. They are used on grazing lands to control unpalatable and noxious plants and to kill brush and small trees that reduce the productivity of pastures and ranges. 2,4-D and other phenoxys are used in canals, ponds, lakes and waterways to kill floating weeds such as water hyacinth, submersed weeds such as pond-weeds, and emergent and shoreline plants such as cattails and willows. Industrial and urban uses include control of brush on utility and transportation rights of way, control of dandelions, plantains, and other weeds in turf and suppression of ragweed, poison ivy and other plants of public health importance.

The principal hazard in the use of the phenoxys is to crops and other valuable plants either within the treated area or nearby. Treated crops and forest trees can be injured through accidental overdosing, improper timing of treatments, unusual weather conditions and other causes. Injury to nearby crops and ornamentals can result from drift of droplets or vapors of the spray. Such losses are largely preventable

CAST 1978 (con't.)

through the use of proper formulations and spray equipment and the exercise of good judgement.

The phenoxy herbicides are predominantly toxic to green plants and are much less toxic to mammals, birds, fish, reptiles, shellfish, insects, worms, fungi and bacteria. When properly used, they do not occur in soils and water at levels harmful to animals and microorganisms. They do not concentrate in food chains and do not persist from year to year in croplands. They are detectable only rarely in food and then only in insignificant amounts.

A highly poisonous kind of dioxin called TCDD is an unavoidable contaminant in commercial supplies of 2,4,5-T and silvex. The amount present in currently produced formulations of 2,4,5-T and silvex is not enough to alter the toxicological properties of these preparations or to endanger human health or to affect plants or animals in the environment.

The phenoxy herbicides are widely used because they are more efficient and usually less hazardous and less injurious to the environment than alternative methods. Use of these chemicals is estimated to reduce the cost of production of the crops on which they are used by about 5% and to reduce overall agricultural production costs in the U.S. by about 1%. Uses in forests and nonagricultural situations provide additional savings. If the phenoxys are no longer available, the cost of food, forest products, electric power, transportation and governmental services would be higher. These costs would be borne by consumers.

Courtney, K. D. 1978. Prenatal development index: a means of evaluation. Teratology 11:15A. (Title unknown, Pesticides and Toxic Substances Effects Lab., EPA, Research Triangle Park, N. Carolina; location where research conducted unknown).

The Prenatal Development Index (PD Index) was derived from the incidence of malformed fetuses, fetal mortality and fetal body weight. This index was used to evaluate the overall effect of a compound on prenatal development as it related to those three parameters. The index also delineated the magnitude of the effect conferring better definition to terms as weak teratogen or strong teratogen. This will be exemplified by data from studied with a structurally related series of compounds of the esters of 2,4,5-T and 2,4-D and related phenoxy herbicides. Many of these compounds produced cleft palates in mice. Some compounds affected fetal weight or mortality disproportionately to the effect on palate development. An overall view of the effects

Courtney 1978 (con't.)

of these compounds on prenatal development and ranking of their effectiveness was determined by the PD Index. In some experiments with toxic compounds the high incidence of fetal mortality and consequently low incidence of malformed fetuses due to the small number of viable fetuses obscured any dose related response. When these parameters were considered together in the PD Index, the dose related response became evident; this will be demonstrated with experimental data from mice.

III. Pollutant and Toxic Hazards
A. Toxicity to Non-Target Organisms
2. Mammals

SUMMARY AND CONCLUSIONS

Toxicity and health hazards associated with the use of 2,4,5-T for brush and weed control began with research published by Courtney et al. (1970). Their research involved 2,4,5-T administered either subcutaneously or orally to mice and rats. Subcutaneous applications of 2,4,5-T were administered in 100% dimethylsulfoxide (DMSO) solutions in a volume of 100 μl/mouse. 2,4,5-T suspended in a honey solution (honey:water, 1:1), was administered orally by a stomach tube in volumes of 100 μl/mouse and 200 μl/rat. Their research indicated that 2,4,5-T produced teratogenic and feticidal effects in both mice and rats. By their own admission, the 2,4,5-T they used was contaminated with 30 ppm dioxin.

Research by Courtney and Colleagues has continued to indicate that 2,4,5-T and/or dioxin are hazardous to the health of mammals, particularly mice and rats (Courtney and Moore, 1971; Moore and Courtney, 1971; and Courtney, 1978). Although Collins and Williams (1971b) were able to show teratogenicity in hampsters resulting from 2,4,5-T they could not find similar effects in mice. Highman et al. (1976) reported similar results. Thompson et al. (1971) reported that no clinical or pathological signs of maternal toxicity were observed in either rats or rabbits that received daily, oral doses of 1 to 50 mg/kg/day (day 6 through 15 of gestation) of 2,4,5-T. They did indicate a toxic effect but no terata in rats receiving oral administration of 100 mg/kg/day (day 6 through 10 of gestation) of 2,4,5-T.

It is generally assumed that teratogenicity, fetacidal, and other toxic effects from 2,4,5-T result from the impurity 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD or dioxin) (Kearney, 1970; Gribble, 1974; Anon, 1975; Frohberg et al., 1977). However, this has not been reported to always be the case (Highman et al., 1976a). Scientists cannot agree among themselves how hazardous dioxin is (Anon., 1973). Studies at Eglin Air Force Base in Florida where massive rates of 2,4,5-T (160,948 lb a.i./mi^2 or 251.5 lb a.i./acre) were used indicated that dioxin was present (10 to 710 parts per trillion) in the top 6 inches of soil 10 years after treatment (Thalken et al., 1975; Young et al., 1975b; Young et al., 1976). Liver tissue of rodents trapped on the test area contained 210 to 1300 parts per trillion dioxin; however, no gross or histological evidence of tetatogenicity or toxicity was found in 122 adults and 87 fetuses (Thalken et al., 1975).

The previous discussion indicates that 2,4,5-T is hazardous and toxic, yet there are several studies that indicate 2,4,5-T is not hazardous to the health of mammals. Emerson et al. (1971) found no clinical or gross pathological sign of adverse effect from 2,4,5-T administered orally to dams of rats (1 to 24 mg/kg on days 6 through 15 of gestation) or rabbits (10 to 40 mg/kg on days 6 through 18 of gestation). Similarly no effect was observed on their offspring nor on the size of their litters. Production of cleft palate is one of the main teratogenic effects reported on mammals, yet King et al. (1971) found cleft palate conditions in only 9 fetuses out of 2231 in rats that had received doses of 60 to 120 mg/kg of 2,4,5-T. Control rats (those receiving no 2,4,5-T) produced a 3.5% resorption rate compared to 2.6% for those receiving 2,4,5-T. Fang et al. found that 2,4,5-T did concentrate in the kidneys, blood, lung, heart and liver of rats, but that the half-life of 2,4,5-T in the blood and vital organs was only 3.5 hr for adults (1966) and 97 hr for the newborn (1973).

Dogs are more susceptible to 2,4,5-T than rats, possibly because the half-life values for clearance from plasma and elimination from the body is longer in the dog and there may also be a difference in metabolism (Piper et al., 1973). But, the effect is dependent upon dosage. 2,4,5-T also rapidly disappears from the bodies of rabbits (Berndt and Koschier, 1973).

Binns and Balls (1971) found no teratogenicity in ewes fed 2,4,5-T at a rate of 100 mg/kg body weight daily from day 14 through 36 of gestation. Rhesus monkey females were receiving 2,4,5-T (up to 10 mg/kg) with 0.05 ppm TCDD and showed no signs of toxicity, nor was there any evidence of teratogenicity among their offspring (Dougherty et al. 1975).

The Council for Agricultural Science and Technology (CAST, 1978) thoroughly reviewed the available information pertaining to phenoxy herbicides. They found 2,4,5-T, as used in the U.S. according to the directions on the label, and Silvex are safe and can be used without hazard to the health of all animals, including humans. The results of their review are supported by Maier-Bode (1974) from Germany.

Lethal doses of the herbicides used to control mesquite have been reported by several authorities (Rowe and Hymas, 1954; Pimental, 1971; Burt and Storm, 1973; Drill and Hiratzka; Ford, 1974; Todd et al., 1974; Morton and Hoffman, 1976). They are summarized in Table 37.

One of the major questions that arise concerning the use of herbicides to control mesquite is "how much residue is present in tissue and milk. St. John et al. (1964) reported that no silvex accumulated in

Table 37. Lethal doses (LD_{50}) and lethal concentrations (LC_{50}) at which 50% of the mammals are killed when treated with the various herbicides used to control mesquite (Pimmental, 1971).

Mammals	Dicamba		Diuron		Fenuron		Monuron		Picloram		Silvex		2,4,5-T		Tebuthiuron	
	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}
Rat	2900 mg/kg		3400 mg/kg		7500 mg/kg		3500 to 3700 mg/kg		8200 mg/kg		1070 mg/kg		300 mg/kg		644 mg/kg	
Mouse									2000 to 4000mg/kg		2140 mg/kg				579 mg/kg	
Rabbit									~2000mg/kg		850mg/kg				286 mg/kg	
Guinea pig									~3000mg/kg		850mg/kg					
Dog													100 mg/kg		>500 mg/kg	
Golden hamster (72-hr)													425mg/kg			
Cats															>200 mg/kg	

milk from dairy cows. Milk samples from cows fed a complete ration containing 2,4,5-T and silvex 1000 ppm for 2 to 3 weeks had the following residues: milk, 0.42 ppm 2,4,5-T and 0.12 ppm silvex (Bjerke et al., 1973). Residues of all chemicals decreased rapidly upon removal of the chemicals from the feed. Leng (1972) reported similar results (Table 38 and 39).

Sheep and cattle fed 2,4,5-T and silvex had residues of the herbicides in their kidneys and liver but none in the muscle and fat (Clark et al., 1975).

Table 38. Average residues of silvex and 2,4,5-trichlorophenol in milk and cream from cows fed silvex for 2 or 3 weeks at each level followed by untreated freed for 1 week (Leng, 1972).

ppm Silvex in Diet	Milk Cow Number			Cream Composite
	96	90	9078	
100	<0.05	<0.05	<0.05	<0.05
300	<0.05	<0.05	<0.05	<0.05
1000	0.08	0.09	0.16	0.16
1000+D	<0.05	<0.05	<0.05	<0.05

Table 39. Average residues of 2,4,5-T and 2,4,5-trichlorophenol in milk and cream from cows fed 2,4,5-T for 2 or 3 weeks at each level followed by untreated feed for 1 week (Leng, 1972).

ppm Silvex in Diet	Milk Cow Number			Cream Composite
	36	7417	30	
10	<0.05	<0.05	<0.05	<0.05
30	<0.05	<0.05	<0.05	<0.05
100	<0.05	<0.05	<0.05	<0.05
300	0.05	0.06	0.20	0.07
1000	0.35	0.31	0.54	0.26
1000+D	<0.05	<0.05	<0.05	<0.05

III. Pollutant and Toxic Hazards

A. Toxicity to Non-Target Organisms

3. Birds

Dobson, N. 1954. Chemical sprays and poultry. J. Min. Agr. 9:415-418. (Ministry of Agriculture and Fisheries, Vet. Lab., Weybridge; research conducted at Weybridge).

Experiments at the Ministry's Veterinary Laboratory, carried out under the aegis of the Agricultural Improvement Council, suggest that in certain circumstances, the exposure of poultry to grassland or orchards regularly sprayed with some common chemical sprays may lead to a serious drop in egg production.

Roberts, R. E. and B. J. Rogers. 1957. The effect of 2,4,5-T brush spray on turkeys. Poult. Sci. 36:703-705. (Titles unknown, Dep. Poultry Science, and Botany and Plant Path., Purdue Univ., Lafayette, Ind.; research conducted at Purdue).

Neither the addition of the 2,4,5-T nor the sprayed alfalfa to the mash had any appreciable effect on the rate of growth or amount of feed consumed. Calculated from the average weight of 18.46 lb for the 11-day period and the average daily feed consumption of 1.04 lb, the birds which received the ration containing 0.25% of the herbicide consumed this material at the rate of 141 mg/kg of body weight/day, equivalent to 62 mg/kg of 2,4,5-T acid/day. To obtain this same dosage, when the herbicide is applied at the rate of 1.6 lb of 2,4,5-T acid/acre, even assuming that all of the herbicide is deposited on the forage, a turkey would have to consume all of the forage on 31 ft^2 of pasture each day, or 100 turkeys all the forage on an acre in about 14 days. The birds which received the ration containing 10% of sprayed (with 2,4,5-T) alfalfa consumed 0.1 lb of the alfalfa/day. Assuming that the ground alfalfa contained 20% moisture, this is equivalent to a consumption of 40 lb of fresh alfalfa (80% moisture)/100 birds/day.

Dewitt, J. B., W. H. Stickel, and P. F. Stringer. 1963. Wildlife studies, Patuxent Wildlife Research Center, p. 74-96. In, Pesticide Wildlife Studies. (U.S. Fish and Wildlife Serv., Circ. No. 167). (Titles unknown, Bureau of Sport Fisheries and Wildlife; research conducted by Patuxent Wildlife Research Center, Md.).

Pesticide research at Patuxent had two principal objectives. One was to appraise new or accepted chemicals to which wildlife might be exposed. This objective was approached through tests of many chemicals on captive birds of selected wildlife species. Both chronic and acute tests were used. The long-term results of adding small amounts of pesticides to the diet were studied through measurements of growth and reproduction. Chemical analyses for residues in wild and experimental animals also contributed to the evaluation of chemicals, for persistence and accumulation in the body are especially dangerous traits of many chemicals.

The other objective was to study major problems that arose from field applications of pesticides. These problems were approached by the combination of methods that seemed most appropriate. The methods often involved both chemical and biological techniques in the field as well as in the laboratory. Enclosure studies that bridged the gap between field and laboratory studies became an important part of the program. Serious efforts were devoted to devising and testing better field and laboratory methods. The kinetics of pesticides--the relation of rates of assimilation and excretion to toxic action and residue levels--was given increased consideration in interpreting results and in planning research.

Results given here are, for the most part, in summary form, and some are compiled from research in progress, so that final tabulations may differ. For these reasons, the findings should not be quoted in technical publications without first communicating with the responsible investigator, who is designated for most studies.

Martin, R. P. 1965. Effects of the herbicide, 2,4,5-T, on breeding bird populations. Oklahoma Acad. Sci., Proc. 46:235-237. (Title unknown, Dep. Zoology, Oklahoma State Univ.; research conducted in Creek Co., Oklahoma).

1. Total populations of nesting birds on 20-acre study areas dominated by postoak-blackjack forest were 17 species and 140 breeding males per 100 acres in the control area compared to 18 species and 205 breeding males in the sprayed area.

Martin 1965 (con't.)

2. The sprayed area provided a suitable habitat for significantly more pairs of the following species: eastern bluebird, eastern meadowlark, mockingbird, mourning dove, and bobwhite. The eastern wood pewee, blue-gray gnatcatcher and brown-headed cowbird had higher populations in the treated area than in the control. Populations of Bell's vireo, brown thrasher, cardinal, yellow-billed cuckoo, summer tanager and yellowshafted flicker were somewhat larger on the control area but the differences could have been the result of factors other than the changes brought about by the use of herbicides.

3. Based on one season's observations the treatment with herbicides had no marked adverse effect upon any nesting species of birds and actually improved the habitat for a few species.

Pimental, D. 1971. Herbicides, p. 85-136. In, Ecological effects of pesticides on non-target species. Exec. Office of President. U.S. Gov't. Printing Office. 220p. (Title unknown, Dep. of Entomology and Limnology, Cornell Univ., N.Y.; summary of published research).

Poland, A. and E. Glover. 1973. 2,3,7,8-tetrachlorodibenzo-p-dioxin: a potent inducer of δ-aminolevulinic acid synthetase. Science 179:476-477. (Titles unknown, Dep. Pharmacology and Toxicology, Univ. Rochester School of Medicine and Denistry, Rochester, N.Y.; research conducted at the Univ. Rochester School of Medicine).

2,3,7,8,-Tetrachlorodibenzo-p-dioxin, a toxic contaminant frequently formed during the synthesis of the herbicide 2,4,5-trichlorophenoxyacetic acid was shown to be a potent inducer of hepatic δ-aminolevulinic acid synthetase in the chick embryo. As little as 4.66×10^{-12} mole of the contaminant per egg produces a significant increase in the activity of the enzyme. Induction of the enzyme is related to the dose of 2,3,7,8-tetrachlorodibenzo-p-dioxin and, in contrast to that produced with other drugs, is prolonged in time, with 70% of the maximum induced activity present 5 days after a single dose. This contaminant is implicated as the likely causative agent in an outbreak of porphyria cutanea tarda in workers in a factory where 2,4,5-trichlorophenoxyacetic acid was being synthesized.

Whitehead, C. C. and R. J. Pettigrew. 1972. The subacute toxicity of 2,4-dichlorophenoxyacetic acid and 2,4,5-trichlorophenoxyacetic acid to chicks. Toxicol Appl. Pharmac. 21:348. (Credentials unknown).

Hussain, S., L. Ehrenberg, G. Lofroth, and T. Gejvall. 1972. Mutagenic effects of TCDD on bacterial systems. AMBIO 1:32. Reported in 1973. Food Cosmet. Toxicol. 11:149-150. (Credentials unknown).

The herbicide 2,4-dichlorophenoxyacetic acid (2,4-D), has a low chronic toxicity in rats and dogs and now it seems that the chick, too, is able to tolerate fairly large doses of 2,4-D and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) given in the form of their butoxyethyl esters.

In 4 week-old chicks, single doses of 2,4-D and 2,4,5-T in the range 250-900 mg/kg caused a temporary reduction in food consumption and a temporary loss of weight and there were some deaths at the highest dosage level. The weight loss was made up after 3 to 4 days and normal growth was resumed. There was no reduction in the growth of newly-hatched chicks maintained for 3 week on diets containing up to 1000 ppm 2,4-D or 100 ppm 2,4,5-T, but higher levels reduced food consumption and growth rate; at levels of 5000 to 7500 ppm 2,4,5-T was lethal and 2,4-D, while it caused no deaths, caused histological changes in the kidney, spleen and other organs. However, the birds were able to tolerate a level of 5000 ppm of either compound for 1 week and resume normal growth thereafter. This level did not affect plasma magnesium or calcium levels. The chicks quickly learnt to distinguish between contaminated and uncontaminated food and ate very little of the former when given the choice.

The teratogenic effects of the 2,4,5-T contaminant, 2,3,7,8-tetrachlorodibenzo-p-dioxin ('dioxin'), are well known and it has been suggested that dioxin's effects on liver enzymes resemble those of certain carcinogens, although the effects considered have also been demonstrated in non-carcinogenic compounds. It is perhaps not surprising, therefore, to find that dioxin has also been associated with mutagenic properties. Escherichia coli Sd-4 showed a high rate of reversion to streptomycin independency in a dioxin concentration of about 2 μg/ml, at a survival rate which excluded a preferential selection of spontaneously occurring mutants. Of two Salmonella typhimurium strains deficient in UV excision repair, one (strain TA 1532) also showed a high mutation frequency at dioxin concentrations causing a survival of less than 50%. Thirdly, dioxin at 0·5 μg/ml partially reversed the inhibition of phage release from E. coli caused by DMSO. The effects resembled those of acridine, and suggested that, like this compound, dioxin acted by intercalation with DNA.

Erne, K. and I. Sperber. 1974. Renal tubular transfer of phenoxyacetic acids in the chicken. Acta Pharmac. Toxicol. 35:233-241. (Titles unknown, Dep. Chemistry, National Vet. Inst. and Dep. Animal Physiology, National Vet. Inst. and Dep. Animal Physiology, College of Agriculture, Upsalla, Sweden; research conducted in Sweden).

The differential renal excretion of phenoxyacetic acid, 2-chlorophenoxyacetic acid, 4-chlorophenoxyacetic acid, 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) was measured in chickens by the method of Sperber (1948 and 1954). Doses of approximately 50 and 100 μmol of either test compound were infused during 3 min into a leg vein and the amounts excreted by the two kidneys determined during consecutive 15-min. periods. At the lower dose level the mean apparent tubular excretion fractions (EF) of the compounds, expressed as per cent of the dose, were 16.5, 22.9, 12.8, 11.3 and 4.2, respectively. All the values except that for 2,4,5-T are sufficiently high to be indicative of tubular excretion. On increasing the dose, the EF values decreased, thus suggesting the involvement of a saturable mechanism. The test compounds proved to depress the excretion of phenol red, the effect being most marked with 2,4,5-T.

Ford, D. H. 1974. Spike® for total vegetation control. Calif. Weed Conf., Proc. 26:25-27. (Plant Science Rep., Eli Lilly & Co., Fresno, Calif.; compilation of several research studies).

Gyrd-Hansen, N. and Dv. Dalgaard-Mikkelsen. 1974. The effect of phenoxy herbicides on the hatchability of eggs and the viability of the chicks. Acta Pharmac. Toxicol. 35:300-308. (Titles unknown, Dep. of Pharmacology and Toxicology, The Royal Vet. and Agr. College, Copenhagen, Denmark; research conducted in Denmark).

The effect of the following phenoxy herbicides: 2,4-D, 2,4,5-T, MCPA, mechlorprop and dichlorprop on the hatchability of hens eggs and the viability of the chicks was investigated both by injecting the herbicides into the yolk and by immersing the eggs in a 1 or 5% solution of the herbicides. The five herbicides were found to have rather similar embryotoxic qualities and the injection of about 2 mg herbicide/60 g egg decreased the percentage hatch and in some

Gyrd-Hansen and Dalgaard-Mikkelsen 1974 (con't.)
cases the viability of the chicks. Immersion in a 1% herbicide solution had no effect and immersion in a 5% herbicide solution had only a moderate effect on the hatchability of the eggs and the viability of the chicks. The embryotoxic effect of 2,7,-dichlorodibenzo-p-dioxin was found to at least 100 times that of the herbicides. In the injection experiments a considerable number of malformations was observed in the dead embryos at the high dose levels.

Somers, J., E. T. Moran, Jr., B. S. Reinhart, and G. R. Stephenson. 1974. Effect of external application of pesticides to the fertile egg on hatchery success and early chick performance. I. Preincubation spraying with DDT and commercial mixtures of 2,4-D: picloram and 2,4-D: 2,4,5-T. Bull. Environ. Contam. Toxicol. 11:33-38. (Titles unknown, Dep. Animal and Poultry Sci., and Dep. Environ. Biology, Univ. of Guelph, Guelph, Ontario, Canada; research conducted at the Univ. of Guelph).

In 2 separate experiments, solutions of DDT, 2,4-D and picloram and 2,4-D + 2,4,5-T were sprayed on fertile chicken eggs preceeding incubation. No treatments were found to cause any adverse effect on hatching success, incidence of malformed embryos or subsequent chick mortality relative to control groups. Weight gain of male chicks from eggs treated with DDT (1.1 kg/ha) and the 2,4-D + 2,4,5-T combination (1.1 and 11.2 kg/ha) was found to be greater than that of control chicks. No changes were noted with the females. Residue analysis verified pesticide penetration into the egg.

Somers, J., E. T. Moran, and B. S. Reinhart. 1974. Effect of external application of pesticides to the fertile egg on hatching success and early chick performance. 2. Commercial-herbicide mixtures of 2,4-D with picloram or 2,4,5-T using the pheasant. Environ. Contam. Toxicol. Bull. 11:339-342. (Titles unknown, Dep. Animal and Poultry Sci., Univ. of Guelph, Guelph, Ontario, Canada; research conducted at Univ. of Guelph).

Somers et al. 1974 (con't.)

Aqueous solutions of 2,4-D:picloram and 2,4-D:2,4,5-T equivalent to recommended and 10x field concentrations, respectively, were sprayed on fertile pheasant eggs preceeding incubation. No treatments were found to cause any adverse effect on hatching success, incidence of malformed embryos or subsequent chick mortality relative to water-sprayed control eggs. Herbicide contamination was found to facilitate weight gain of males from 0 to 4 weeks of age while females failed to elicit a response. Residue analysis verified herbicide deposition on the shell and entry into the egg. These results completely paralleled those of an earlier study with the domestic chicken.

Bartelson, F. D., Jr., D. D. Harrison, and J. D. Morgan. 1975. Wildlife observations on TA C-52A (Birds, Annotated list of birds on TA C-52A), p. 15-28. In, Field studies of wildlife exposed to TCDD contaminated soils. Final report ending February, 1975. Air Force Armament Laboratory. (Eglin Air Force Base, Florida). (Lt. Col., unknown title and 1st Lt. (USAF), respectively; research conducted at Eglin Air Force Base).

Seventy-seven species of birds were observed on TA C-52A. Of this number, 44 species were observed on Grid 1. The remaining birds were seen in the surrounding clearing and bayheads projecting into the clearing.

Only three species can be classified as residents which nest on the large grid. These are the southern meadowlark (*Sturnella magna*), the mourning dove (*Zenaidura macroura*), and the bobwhite quail (*Colinus virginianus*). There were no nesting resident birds on Grid 1.

At the beginning of the study, in the spring of 1974, the meadowlark was the dominant bird of the large grid and the surrounding cleared area. They could be found in nearly all areas containing low shrubs and were most abundant in the areas around the northeastern and northwestern corners of the large grid. These birds were rarely seen south of the middle of the large grid except near the bayheads. Since meadowlarks were the most numerous birds of the study area, they were selected for analysis of TCDD in liver tissue. Nine specimens were collected during the second week of May along the F and G rows of the 1 mi^2 grid.

During the late spring and summer there was a gradual but marked decrease in the number of these birds. Part of the decline was due to the collection of specimens and to the normal spring migration of winter visitors, but the number continued to decline after these events

A nest containing five eggs was discovered on 11 July in the northeastern section of the large grid (near marker B-12), but the nest was molested and eggs disappeared on the night of 17 July. The decline in the meadowlark population continued during and after the breeding season. Young meadowlarks were first seen in the area in late May and appeared to outnumber adults by the end of June. By mid-summer, meadowlarks had become quite scarce and no more than a dozen birds were observed in 1 day; more frequently, none was seen or heard.

Three more specimens (one adult and two immature birds) were collected in the first week of August. The adult specimen, a male, was in an apparent bad state of health. The feathers were badly frayed and sparce. The skin was very reddened, and the scales of the feet and legs were cracked, swollen, and rough. The tip of the normally pointed, horny tongue was truncated and frayed. The testes and liver were both enlarged, but other internal structures appeared normal. The stomach contents were largely insect remains, with a small amount of vegetative matter. Darkling beetles (Family Tenebrionidae) were the principal insect remains. The two immature meadowlarks appeared normal; their livers and stomachs, including contents were analyzed for TCDD.

Until mid-September meadowlarks were very scarce, but then they appeared in rapidly increasing numbers. On both 24 and 26 September, over 150 meadowlarks were seen on and around the northern edge of the large grid. Most of these birds were obviously transient migrants passing through the area because by mid-November the numbers had dropped to about 50 or 60. In early December only 15 to 20 remained in the immediate area and occasionally were found on the large grid, but in January they were rarely seen.

Mourning doves were seen regularly during most of the study, either as singles or in groups up to four, but were rare in late December and January. These seed-eaters ranged over a larger area than the meadowlarks, and could even be found occasionally on Grid 1. In the spring, at the beginning of the study, mourning doves were much less common than the meadowlarks, but they gradually became more abundant than the meadowlark. Local breeding of the doves was obviously quite successful. Surprisingly, four dove nests, each containing two eggs, were discovered on the ground of the large grid. This is quite unusual, but ground nests have been reported by Howell and Weston. By mid-August well over 100 doves were present on TA C-52A. With the arrival of migrants, this number was doubled by mid-September. By December the population of doves had returned to approximately 25, and by January they were seldom seen. Six mourning doves were collected from the large grid in May, and three additional specimens were collected from Grid 1 in November for TCDD analysis.

Bobwhite quail were frequently heard calling and occasionally seen in the northern half of the large grid and around the bayheads in spring and early summer. The numbers of these birds residing on or visiting the grid were apparently quite small. One quail nest containing 10 chicks was discovered near marker D-5 in the northwest section.

Bartelson et al. 1975 (con't.)

The only other group of quail seen on the grid was a covey of five. No quail were heard or seen on the grid after July.

Kenega, E. E. 1975. The evaluation of the safety of 2,4,5-T to birds in areas treated for vegetation control. Residue Rev. 59:1-19. (Title unknown, The Dow Chemical Co., Midland, Mich.; literature review).

2,4,5-T (2,4,5-trichlorophenoxyacetic acid) and its salts and ester derivatives and formulations are recommended for use in the contr l of woody and herbaceous weed plants at dosages ranging from 0.5 to 16 lb of 2,4,5-T acid equivalent/A. Residues on treated plants, based on a 1 lb of 2,4,5-T/A application, range downwards from 144 ppm, depending on climate, time after application, spray coverage, vegetative density, vegetative surface-area-to-volume ratio, and other factors. 2,4,5-T and derivatives are metabolized or degraded by microorganisms, birds, plants, sunlight, etc., often rapidly.

Dietary levels of 2,4,5-T and derivatives causing no effect, or LC_{50} in laboratory tests, are high enough so that they normally exceed the residues expected in dietary food of birds in treated areas. It is concluded that birds in areas treated with recommended dosages of 2,4,5-T, and ester and salt derivatives should not be affected acutely or chronically in the egg, chick, or adult stages of life.

Morton, D. M. and D. G. Hoffman. 1976. Metabolism of a new herbicide, tebuthiuron (1-(5-(1,1-dimethylethyl)-1,3,4-thiadiazole-2-yl)-1,3-dimethylurea), in mouse, rat, rabbit, dog, duck, and fish. J. Toxicol. Environ. Health 1:757-768. (Titles unknown, Toxicology Div., Lilly Research Labs., Greenfield, Indiana; research conducted at Greenfield).

Orally dosed tebuthiuron was readily absorbed in mice, rats, rabbits, dogs, and ducks. The compound was extensively metabolized and the metabolites were rapidly excreted in the urine of mice, rats, rabbits, and dogs and in the mixture of urine and feces in ducks. The major metabolites of tebuthiuron were formed by N=demethylation of the substituted urea side chain in each species examined, including fish. Oxidation of the dimethylethyl group occurred in mice, rats, dogs, rabbits, and ducks. The N-demethylation reaction at the 3-position

Morton and Hoffman, 1976 (con't.)

of the urea proceeded through an N-hydroxymethyl intermediate. No accumulation of tebuthiuron or its metabolites was observed in the animals, a finding consistent with the low order of toxicity observed in other studies.

Young, A. L., C. E. Thalken, E. L. Arnold, J. M. Cupello, and L. G. Cockerham. 1976. Fate of TCDD in an ecosystem (rodent studies), p. 23-27. In, Fate of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) in the environment: summary and decontamination recommendations. USAFA-TR-76-18. (Capt. (Ph.D.), Major (DVM), Lt. Col. (Ph.D.), Capt. (Ph.D.), and Major (M.S.), respectively, Dep. Chemistry and Biological Sciences, USAF Academy, Colorado; research conducted at Eglin AFB, Florida, Garden City, Kansas, and Air Force Logistics Command Test Range Complex, Utah).

Studies on the fate of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) have been conducted on biodegradation plots and field test areas that have received massive quantities of Orange herbicide (a 50:50 mixture of the n-butyl esters of 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). From the studies reviewed in this report, it is apparent that (1) although TCDD may persist in the environment for long periods of time (greater than 12 years) when initially present at high concentrations on the soil surface, it may be degraded by soil microorganisms, especially when in the presence of other chlorinated hydrocarbons (an estimated half-life for TCDD in the presence of 2,4-D and 2,4,5-T herbicides is 225 to 275 days); (2) TCDD may accumulate in the tissues of rodents, reptiles, birds, fish, and insects when these organisms are exposed to TCDD contaminated soils (however, the levels of TCDD in the tissues apparently do not exceed the levels of TCDD found in the environment); (3) rodents, reptiles, birds, fish and insects may tolerate, i.e., based on no observed deleterious effects in field studies, soil levels between 10 to 1,500 ppt TCDD; (4) TCDD may be degraded in the presence of sunlight; (5) movement of TCDD in the abiotic portions of the environment can be by wind or water erosion of soil particles, but leaching by water alone does not appear to occur: and (6) TCDD is probably not readily released or degraded in the environment when bound to activated coconut charcoal.

III. Pollutant and Toxic Hazards
A. Toxicity to Non-Target Organisms
3. Birds

SUMMARY AND CONCLUSIONS

Dobson (1954) reported that 2,4,5-T caused a reduction in egg production and a weight loss in poultry, but it did not affect either fertility or hatchability of the eggs. More recent research indicates there essentially is no adverse effects on birds if herbicides are applied at recommended rates.

Neither 2,4,5-T added to the mash nor sprayed on alfalfa fed to turkeys affected growth rate or amount of feed consumed (Roberts and Rogers, 1957). Single doses of 2,4,5-T (250 to 900 mg/kg body weight) to 4 week old chicks caused a temporary loss of weight and some deaths at the higher dosage, but weight loss was overcome in 3 to 4 days and normal growth was resumed (Whitehead and Pettigrew, 1973). Native birds were not adversely affected by spraying 2,4,5-T in Oklahoma (Martin, 1965); in fact, a better nesting habitat resulted for some species.

Immersion of hen eggs in a solution containing 1 to 5% 2,4,5-T had only a moderate effect on hatchability of the eggs and viability of the chicks, but injection of 2 mg of the herbicide into a 60 g egg decreased the hatch and sometimes affected the viability of the chicks (Gyrd-Hansen and Delgaard-Mikkelsen, 1974). They found that dioxin was much more toxic than 2,4,5-T. Somers et al. (1974a, 1974b), cognizant of results from external and internal application on avian eggs attempted to simulate field application of 2,4,5-T and evaluate its effects on pheasant eggs. They found no adverse effects on hatching success, teratogenicity or subsequent mortality to chicks from fertile eggs that had been sprayed with 2,4,5-T. Massive rate herbicides containing dioxin were sprayed on Eglin Air Force Base in Florida. TCDD accumulated in the food chain, but no positive evidences of deleterious effects were found (Bartleson et al., 1975).

Kenega (1975) reviewed 36 publications reporting use of 2,4,5-T in areas inhabited by birds. He concluded that when 2,4,5-T is used according to the directions on the label (rates ranging from 0.5 to 16.0 lb/acre), there is no health hazard to birds, as well as other non-target organisms. There seems to be little evidence that would warrant restricted use of 2,4,5-T because of defoliation effects on birds.

Lethal doses and lethal concentrations have been reported for a few birds (Pimental, 1971; Ford, 1974; Morton and Hoffman, 1976). They are summarized in Table 40.

Table 40. Lethal dose and lethal concentration at which 50% of the population of the listed birds is killed by the various herbicides used to spray mesquite (Pimmental, 1971).

Birds	Dicamba		Diuron		Fenuron		Monuron		Picloram		Silvex		2,4,5-T		Tebuthiuron	
	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}
Pheasant (female)	673															
Pheasant (male)	800															
Pheasant (young)				>5000ppm		>5000ppm		4000 to 5000ppm	>2000 mg/kg	>5000ppm		3000 to 5000ppm		1250 to 2500ppm		
Mallards (young)			>2000 mg/kg	>5000ppm		>5000ppm		>5000ppm	>2000 mg/kg	>5000ppm				>5000ppm		
Bobwhite quail (young)				2000 to 2200ppm	>2300 mg/kg										>500 mg/kg	
Cortunix (young)				>5000ppm		>5000ppm		>5000ppm				>5000ppm		>5000ppm		
Chicks									6000 mg/kg						>500 mg/kg	
Ducks															>500 mg/kg	

Young, A. L., C. E. Thalken, E. L. Arnold, J. M. Cupello, and L. G. Cockerham. 1976. Fate of TCDD in an ecosystem (reptiles studies), p. 29-30. In, Fate of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) in the environment: summary and decontamination recommendation. USAFA-TR-76-18. (Capt. (Ph.D.), Major (DVM), Lt. Col. (Ph.D.), Capt. (Ph.D.), and Major (M.S.), respectively, Dep. Chemistry and Biological Sciences, USAF Academy, Colorado; research conducted at Eglin AFB, Florida, Garden City, Kansas, and Air Force Logistics Command Test Range Complex, Utah).

Studies on the fate of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) have been conducted on biodegradation plots and field test areas that have received massive quantities of Orange herbicide (a 50:50 mixture of the n-butyl esters of 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). From the studies reviewed in this report, it is apparent that (1) although TCDD may persist in the environment for long periods of time (greater than 12 years) when initially present at high concentrations on the soil surface, it may be degraded by soil microorganisms, especially when in the presence of other chlorinated hydrocarbons (an estimated half-life for TCDD in the presence of 2,4-D and 2,4,5-T herbicides is 225 to 275 days); (2) TCDD may accumulate in the tissues of rodents, reptiles, birds, fish, and insects when these organisms are exposed to TCDD contaminated soils (however, the levels of TCDD in the tissues apparently do not exceed the levels of TCDD found in the environment); (3) rodents, reptiles, birds, fish and insects may tolerate, i.e., based on no observed deleterious effects in field studies, soil levels between 10 to 1,500 ppt TCDD; (4) TCDD may be degraded in the presence of sunlight; (5) movement of TCDD in the abiotic portions of the environment can be by wind or water erosion of soil particles, but leaching by water alone does not appear to occur; and (6) TCDD is probably not readily released or degraded in the environment when bound to activated coconut charcoal.

III. Pollutant and Toxic Hazards
A. Toxicity to Non-Target Organisms
4. Reptiles

SUMMARY AND CONCLUSIONS

The literature is basically devoid of toxic effects of herbicides to reptiles. Young et al. (1976) conducted chemical analysis for TCDD in the body parts of the six-lined racerunner. Results reported herein are from studies on Agent Orange and TCDD. They found significant levels of TCDD (360 to 370 ppt) in the visceral mass and in the trunk of the racerunners on the test sites. However, they did find not find any evidence of gross abnormalities in any of the specimens collected during the study.

Butler, P. A. 1963. Commercial fisheries investigations, p. 11-25. In, Pestic. Wildlife Studies. U.S. Fish Wildlife Serv. Circ. No. 167. (Title unknown, Bureau of Commercial Fisheries; research conducted at the Biological Lab. at Gulf Breeze, Florida).

Laboratory and field studies have shown many of the commonly used pesticides to be highly toxic to certain species of fresh-water fishes. The data reported here are the results of bioassays to determine the relative toxicity of pesticides to marine species. Because of their abundance in local waters and the commercial importance of mullet, juvenile white mullet (*Mugil curema*), and longnose killifish (*Fundulus similis*) were used as test animals in acute toxicity tests.

Twenty-four- and 48-hr median tolerated limit values, TLm, were obtained by exposing groups of 10 fish to five or more concentrations of each chemical. Unless otherwise noted, the tests were conducted in running sea water aquaria. The toxicity values in table 6A were determined by graphical interpolation of test results.

Many marine fish pass their early growth stages in estuaries, the so-called nursery areas. The effects of chronic low-level pollution are, therefore, of considerable importance.

Three groups of spot (*Leiostomus xanthurus*) approximately 1 inch long were exposed continuously for 3 months to sublethal concentrations of dieldrin (0.1, 0.01, and 0.001 parts per billion) in running sea water. Mortalities were high, 30 to 37%, but not significantly different in control and experimental groups. Neither were there significant differences in the attained mean standard lengths of the different groups. However, some of the experimental fish had axial skeletal distortions that were not apparent in the control group.

Survivors of the experiment were exposed to 2 ppb of dieldrin to determine whether earlier low-level exposure had created any resistance to dieldrin. Eighty percent of the experimental fish survived 24-hr exposure to the dieldrin, while in a group of previously unexposed fish there were no survivors.

David, J. T. and J. S. Hughes. 1963. Further considerations on the toxicity of commercial herbicides to bluegill sunfish. Southern Weed Conf., Proc. 16:337-340. (Fisheries Biologists, Louisiana Wildlife and Fisheries Commission, Monroe, La.; location where research conducted unknown).

New and reformulated herbicides are appearing on the market constantly. Prior to this marketing they are screened to determine their acceptability. Before they receive wide acceptance and use, they must have the proven ability to kill weeds and not seriously damage crops. In aquatic environments, it is necessary to determine their effects on both fish and fish food organisms.

Hughes, J. S. and J. T. Davis. 1963. Variations in toxicity to bluegill sunfish of phenoxy herbicides. Weeds 11:50-53. (Fisheries Biologists, Louisiana Wildlife and Fisheries Commission, Monroe, La.; research conducted at Monroe Fish Hatchery).

The toxicity to bluegill sunfish of 3 to 21 commercial formulations of 2,4-dichlorophenoxyacetic (2,4-D), 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), 2-(2,4-dichlorophenoxy)propionic acid (2-(2,4-DP), and 2-(2,4,5-trichlorophenoxy)propionic acid (silvex) was determined. The variations among formulations of the same herbicide were much greater than those among different herbicides. Variations in toxicity of a single formulation were also noted. Formulations of each herbicide were reported as either safe or unsafe for aquatic applications. Amine salts were generally less toxic to fish than esters. The formulation selected for use should be assayed prior to field application, using the receiving water.

Butler, P. A. 1965. Effects of herbicides on estuarine fauna. Southern Weed Conf., Proc. 18:576-580. (Title unknown, Bureau of Commercial Fisheries, Biological Lab., Gulf Breeze, Florida; research conducted at the Biological Lab).

Pimental, D. 1971. Herbicides, p. 85-136. In, Ecological effects of pesticides on non-target species. Exec. Office of President. U.S. Gov't. Printing Office. 220p. (Title unknown, Dep. of Ento. and Limnology, Cornell Univ., N.Y.; summary of published research).

Mullison, W. R. 1972. Ecological effects of herbicides. Down to Earth 28:21-24. (Title unknown, Ag-Organic Dep., Dow Chemical Co., summary article).

Organic herbicides have been extensively studied and used for a relatively short period of time, approximately the last 30 years. Nonetheless, during this time, their ecological effects in modifying man's environment have been well recognized. Thus, herbicides are used for the selective killing of unwanted plants, i.e. weeds, according to man's desires and for his benefits.

Experience to date indicates a vast preponderance of beneficial results from the proper use of herbicides.

Fears that they will render the soil permanently sterile are unfounded, as they break down in the soil. Most commercial herbicides now in use are low in toxicity to man and animals. Further, they are now used in such a way that they do not accumulate and create a hazard in our environment.

Man's tools frequently are used to interfere with nature, and herbicides are a powerful tool. As is true with others of man's tools, it is the wisdom with which they are used that will determine whether they have a beneficial or harmful ecological effect.

Shapley, D. 1973. Herbicides: AAAS study finds dioxin in Vietnamese fish. Science 180(4083):285-286. (Credentials unknown).

Fish and shellfish from areas of South Vietnam that were heavily sprayed during the U.S. defoliation campaign contain significant quantities of dioxin, according to two Harvard scientists, Robert Baughman and Matthew Meselson. Dioxin, a contaminant of some herbicides, is known to be an extremely potent agent in causing birth defects. The finding is the first solid evidence that dioxin entered the diet of the Vietnamese people and could, thereby have posed a hazard to human health there.

Shapley 1973 (con't.)

The fish were bought in 1970 from markets where Vietnamese housewives also obtained their fish. "We will not say this poses an immediate problem to health. . .but there is plenty of room to be worried," said Meselson. "There is no evidence for catastrophic illness, but whether it was making significant, but not catastrophic, health problems, we don't know."

The two scientists have cautiously refrained from asserting that finding dioxin in fish proves that U.S. herbicides are responsible for reported rises in stillbirths and birth defects in heavily sprayed provinces of South Vietnam. Their report speaks to that point more gingerly, saying that dioxin "may have accumulated to biologically significant levels in food chains in some areas of South Vietnam exposed to herbicide spraying." They presented their paper on 2 April at a conference on dioxins sponsored by the National Institute for Environmental Health Sciences.

The disclosures brought an immediate response from the Center for the Study of Responsive Law, an organization associated with Ralph Nader. The center called on EPA administrator William Ruckelshaus to suspend all uses of 2,4,5-T and silvex--two dioxin containing herbicides now in wide use in the U.S. The center also urged Ruckelshaus to begin a systematic hunt for dioxin in food chains in this country.

A second policy repercussion of the Baughman-Meselson paper would be to further hamper Air Force plans to sell up to 2.3 million gal surplus Agent Orange to Brazil, Venezuela, and Paraguay. The center's letter to Ruckelshaus also urged him to reject an Air Force application to EPA to approve the Agent Orange and for foreign export.

Meselson collected the fish samples in 1970 during a study trip made by the AAAS Herbicide Assessment Commission which he headed. The samples were frozen, Meselson says, until he and Baughman could develop a new and highly sensitive technique for measuring extremely small amounts of dioxin. The commission has so far produced only one 8-page report, and no firm date is set for the completion of the final report to the AAAS.

The fish were taken from four locations in Military Region III, which includes Saigon and several provinces north of it. Samples were found to have an average dioxin concentration of 540 parts per trillion (ppt) with the range being from 18 to 814 ppt. Other researchers have shown that guinea pigs fed with dioxin at a concentration of 600 ppt have only a 50% chance of survival.

Precisely how the fish became contaminated with dioxin is still a mystery. Dioxin is known to be present in Agent Orange, the principal herbicide used by the U.S. in Vietnam from 1962 until 1970 when its use was ordered discontinued following reports of possible teratogenic effects.

Shapley 1973 (con't.)

"We haven't ruled out other sources for the TCDD (dioxin)," Meselson said in an interview.

Interest in dioxin, a proven teratogen in laboratory animals, intensified after reports by the AAAS Herbicide Assessment Commission and other groups in 1970 indicated that in Vietnam, coincident with the spraying of Agent Orange, the numbers of stillbirths, placental tumors, and malformations rose. But finding that dioxin entered the Vietnamese diet does not, so far, prove that herbicides caused the rise in birth defects in Vietnam. John Constable, of the Harvard Medical School and Massachusetts General Hospital and the medical member of the AAAS team, says the Baughman-Meselson study has "greatly increased my enthusiam for looking into this. Their work is impressive in that it shows that in towns away from the direct exposure to the spraying, dioxin is present."

Constable urged wide sampling of human tissue to ascertain whether people there do in fact carry body burdens of dioxin. Indeed, this question could be answered when Baughman and Meselson complete their analyses of Vietnamese mothers' milk, which they collected from women at the same time as they collected the fish samples in 1970. Although they say the work on mothers' milk will be ready in a few months, both scientists are keeping absolutely mum about their first test results.

The new findings come at a time when other research on dioxin indicates that it is very harmful even in very minute doses. So, no matter what these findings eventually prove about the effects of the U.S. herbicide spraying in Vietnam, they will most probably have an impact on controversies in this country over the use of dioxin-containing chemicals, especially over 2,4,5-T and silvex.

Davis, P. W., J. M. Friedhoff, and G. A. Wedemeyer. 1974. Organochlorine insecticide, herbicide and polychlorinated biphenyl (PCB) inhibition of NaK-ATPase in rainbow trout. Environ. Contam. Toxicol., Bull. 8:69-72. (Titles unknown, Dep. Pharmacology, Univ. Washington, School of Medicine and Western Fish Disease Lab., USDI, Seattle, Wash.; research conducted in Washington).

Davis et al. 1974 (con't.)

The current widespread presence of chlorinated insecticides, polychlorinated biphenyls (PCB's) and herbicides in world waterways has elicited much interest in the mechanisms of their toxicity in fishes. Inhibition of Na^{+}, K^{+}-activated adenosinetriphosphatase (NaK-ATPase) and Mg^{++}-dependent ATPase (Mg-ATPase) by DDT, endosulfan and dicofol has been demonstrated in gill, brain and kidney microsomes of rainbow trout. Intestinal and gill ATPases in marine teleosts were recently reported to be sensitive to organochlorines. Cutkomo et al. noted inhibition of NaK-ATPase and Mg-ATPase in bluegill brain, liver, muscle and kidney by DDT and related chlorinated hydrocarbons. Inhibition of ATPases by PCB's has been recently shown in bluegill kidney, brain and liver. In the present study, we have further examined the NaK-ATPase enzyme system in trout gill as a site for the possible toxicity of selected organopolychlors, i.e., chlorinated insecticides, herbicides and PCB's.

Ford, D. H. 1974. Spike® for total vegetation control. Ann. Calif. Weed Conf., Proc. 26:25-27. (Plant Sci. Representative, Eli Lilly and Company, Fresno, Calif.; location of research unknown).

Based on the results from extensive research and experimental permit demonstration trials conducted throughout the United States, SPIKE® 80W has demonstrated the following advantages for total vegetation control on noncropland areas:

1. Controls a broader spectrum of herbaceous weeds and woody plants than currently available herbicides.

2. Provides long residual control.

3. Demonstrates good stability on soil surfaces.

4. Exhibits negligible lateral movement in soil.

5. Compatible with several other commercially available herbicides.

6. Relatively safe to humans, and poses no hazard to wildlife, birds or fish.

Kenaga, E. E. 1974. 2,4,5-T and derivatives: toxicity and stability in the aquatic environment. Down to Earth 30(3):19-25. (Title unknown, Health and Environmental Research Dep., Dow Chemical Co.; literature review).

The toxicity of 2,4,5-T and its derivatives to fish, shrimp, oysters, aquatic intertebrates, and marine and fresh water algae are summarized. Except for certain esters, 2,4,5-T in most kinds of water, except highly acidic waters, are usually hydrolyzed within a matter of days. Fish also rapidly hydrolyze esters of chlorophenoxy alkanoic acids. Because of the rather rapid hydrolysis, even the more toxic esters of 2,4,5-T should not pose prolonged hazards to aquatic animal and algal organisms under normal use conditions.

Morton, D. M. and D. G. Hoffman. 1976. Metabolism of a new herbicide, tebuthiuron (1-(5-(1,1-dimethylethyl)-1,3,4-thiadiazole-2-yl)-1,3-dimethylurea), in mouse, rat, rabbit, dog, duck, and fish. J. Toxicol. Environ. Health 1:757-768. (Titles unknown, Toxicology Div., Lilly Research Labs., Greenfield, Indiana; research conducted at Greenfield).

Orally dosed tebuthiuron was readily absorbed in mice, rats, rabbits, dogs, and ducks. The compound was extensively metabolized and the metabolites were rapidly excreted in the urine of mice, rats, rabbits, and dogs and in the mixture of urine and feces in ducks. The major metabolites of tebuthiuron were formed by N-dimethylation of the substituted urea side chain in each species examined, including fish. Oxidation of the dimethylethyl group occurred in mice, rats, dogs, rabbits, and ducks. The N-demethylation reaction at the 3-position of the urea proceeded through an N-hydroxymethyl intermediate. No accumulation of tebuthiuron or its metabolites was observed in the animals, a finding consistent with the low order of toxicity observed in other studies.

Young, A. L., C. E. Thalken, E. L. Arnold, J. M. Cupello, and L. G. Cockerham. 1976. Fate of TCDD in an ecosystem (rodent studies), p. 23-27. In, Fate of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) in the environment: summary and decontamination recommendations. USAFA-TR-76-18.

Young et al. 1976 (con't.)
(Capt. (Ph.D.), Major (DVM), Lt. Col. (Ph.D.), Capt. (Ph.D.), and Major (M.S.), respectively, Dep. Chemistry and Biological Sciences, USAF Academy, Colorado; research conducted at Eglin AFB, Florida, Garden City, Kansas, and Air Force Logistics Command Test Range Complex, Utah).

Studies on the fate of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) have been conducted on biodegradation plots and field test areas that have received massive quantities of Orange herbicide (a 50:50 mixture of the n-butyl esters of 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). From the studies reviewed in this report, it is apparent that (1) although TCDD may persist in the environment for long periods of time (greater than 12 years) when initially present at high concentrations on the soil surface, it may be degraded by soil microorganisms, especially when in the presence of other chlorinated hydrocarbons (an estimated half-life for TCDD in the presence of 2,4-D and 2,4,5-T herbicides is 225 days); (2) TCDD may accumulate in the tissues of rodents, reptiles, birds, fish, and insects when these organisms are exposed to TCDD contaiminated soils (however, the levels of TCDD in the tissues apparently do not exceed the levels of TCDD found in the environment); (3) rodents, reptiles, birds, fish and insects may tolerate, i.e., based on no observed deleterious effects in field studies, soil level between 10 to 1,500 ppt TCDD; (4) TCDD may be degraded in the presence of sunlight; (5) movement of TCDD in the abiotic portions of the environment can be by wind or water erosion of soil particles, but leaching by water alone does not appear to occur; and (6) TCDD is probably not readily released or degraded in the environment when bound to activated coconut charcoal.

Gontarek, B. D. 1979. Responses of seven fish species to 2,4,5-T. M.S. Thesis. Texas Tech Univ., Lubbock. 61p. (Grad. Research Asst., Texas Tech Univ.; research conducted at Texas Tech University).

Seven fish species raised in aquaria received repeated exposures of two 2,4,5-T formulations in parts per billion (ppb) concentrations. Largemouth bass (*Micropterus salmoides*), white crappie (*Pomoxis annularis*), black bullhead catfish (*Ictalurus melas*), channel catfish (*I. punctatus*), and a green-redear sunfish hybrid (*Lepomis cyanellus* x *L. microlophus*) were exposed to the triethylamine 2,4,5-T formulation. Two other species, sharpnose shiners (*Notropis oxyrhynchus*) and red shiners (*N. lutrensis*) were exposed to the isooctyl ester 2,4,5-T formulation. Treatment levels ranged from 25 to 400 ppb, the number of exposures varied from 2 to 9, and time between exposures was from 2 to 5 weeks.

Gontarek 1979 (con't.)

Duration of the experiments was from 9 to 18 weeks. The treatments were not responsible for mortailities or differences in growth. Some accumulation of 2,4,5-T residues in tissues at ppb levels did occur in most of the fish species tested. No dioxin residues were found in any fish tissues. The "no effect" results suggest that 2,4,5-T residues which might enter an aquatic system following its use on land would not present any serious hazard to fish populations.

III. Pollutant and Toxic Hazards
A. Toxicity to Non-Target Organisms
5. Fish

SUMMARY AND CONCLUSIONS

Aquatic organisms often receive the most critical scrutiny if there is a possible hazardous effect from pollutants. However, the literature is not overwhelmed with information pertaining to the effects of herbicides used to control mesquite on aquatic organisms. There are some very detailed evaluations of toxic effects recorded in a few papers.

As one would expect, scientists have found significant quantities of dioxin in fish and shellfish collected from aquatic communities of South Vietnam (Shapley, 1973). The herbicides used in South Vietnam, commonly called "agent orange" is not the same herbicide used to control mesquite in the U.S., even though 2,4,5-T is one of the components. We should be cautious about drawing conclusions from results obtained from South Vietnam.

There are a few publications that report detailed effects (or lack of them) of herbicides on aquatic organisms in the U.S. Hughes and Davis (1963) found as much, or more, variations between formulations of a herbicide as they did among herbicides on the effects of bluegill sunfish. They conclude that amine salts of 2,4,5-T and silvex are less toxic than ester formulations. They also indicate that "hard" water will generally reduce toxicity of most herbicides.

Gontarek (1979) found that 2,4,5-T (25 to 400 ppb repeated 2 to 9 times) used appropriately would not present any serious hazard to several fish species; largemouth bass, white crappie, black bullhead catfish, channel catfish, a green-redear sunfish hybrid, sharpnose shiners and red shiners. He found no dioxin in fish tissues analyzed.

Butler (1965) reported the effect of various herbicides on estuarine fauna (Table 41). He concluded that herbicides generally are less toxic than other pesticides. Kenaga (1974) summarized the effect of 2,4,5-T and its derivatives on the toxicity caused to an aquatic environment. His results are presented in Table 42.

Pimental (1971), Ford (1974) and Morton et al. (1976) have summarized the effect of herbicides on fish and molluscs (Table 43 and 44).

Table 41. Relative toxicity of herbicides to estaurine organisms (Butler, 1965).

Herbicide	Oysters	Shrimp	Fish	Phytoplankton
	96-hr EC_{50} [1] ppm(mg/liter)	48-hr EC_{50} [2] ppm(mg/liter)	48-hr LC_{50} [3] ppm(mg/liter)	Percent Decrease [4] at 1.0 ppm
Phenoxy Acids and Derivatives				
2,4,5-T, acid	[5] ne at 2.0	ne at 1.0(B) [6]	ne at 50 [7] (M) [8]	0
2,4,5-T, Polyglycol butyl ether ester	0.14	20% at 1.0(B)	0.32 (S)	89
Silvex, Polyglycol butyl ether ester	23% at 1.0	0.24 (B)	0.36 (S)	78
Veon 245 (2,4,5-T formulation)	ne at 1.0	ne at 1.0 (B)	ne at 1.0(S)	0
Urea Compounds				
Diuron	1.8	ne at 1.0 (B)	6.3 (M)	87
Fenuron	ne at 2.0	10% at 1.0(B)	ne at 1.0(S)	41
Monuron	12% at 2.0	ne at 1.0 (W)	16.3 (M)	94

1/ 96-hr EC_{50} = Concentration of herbicide in sea water causing a 50% decrease in oyster shell growth.

2/ 48-hr EC_{50} = Concentration of herbicide in sea water causing mortality or paralysis to 50% of adult shrimp tested.

3/ 48-hr EC_{50} = Concentration of herbicide in sea water causing 50% mortality to juvenile fish.

4/ Percent decrease = Percent decrease in productivity (carbon fixation) of natural phytoplankton communities during a 4-hour exposure to 1.0 ppm of the indicated herbicide.

5/ ne = no effect

6/ B = brown shrimp, *Penaeus eztecus*
P = pink shrimp, *Penaeus duorarum*
W = white shrimp, *Penaeus setiferus*

7/ Results obtained from standing water tests.

8/ S = spot, *Leiostomus xanthurus*
K = longnose killifish, *Fundulus similis*
M = mullet, *Mugil cephalus*
C = *Cyprinodon variegatus*

Table 42. Toxicity of 2,4,5-T and its derivatives to fish (Kenega, 1974).

Species of fish	Water temp °C	Hours exposure	Commercial Formulation Tested	Dosage (ppm) a.i.	Dosage (ppm) a.e.	% Mortality	Reference
(A) 2,4,5-T							
Longnose	19°	24		5.0F	50.0°	0	1
killifish		48			50.0	0	
Sea Lamprey		24	Unnamed		2.0	0	4
Lake emerald	5-7	72			60	0	3
shiner					75	100	
Fathead minnow	18	72		>100F	200	0	3
					300	100	
(B) 2,4,5-T, Sodium Salt							
Bluegill	22-25	12 (days)		50	45.9	0	6
(C) 2,4,5-T Dimethylamine Salt	25	24	2,4,5-T Amine	172	144	50'	7.0
Bluegill		48	2,4,5-T Amine	172	144	50'	7.0
(D) 2,4,5-T, Triethylamine Salt							
Bluegill	25	24	Crop Rider	75	53.7	50	5.0
			Amine 4T2	74	53.0	50	
	18	24	DED-WEED				
		96	(56.7% a.i.)	>100	72	50	9
				>100	>72	50	
Channel catfish	17	24	DED-WEED	>100	>72	96	8
		96		>100	>72	98	
Rainbow trout	13	24	DED-WEED	>100	>72	50	8
		96		0.1-1.0	0.07-0.72	50	9
Spot	27	24	VEON® 245	1.0F	0.4	0	3
				1.0F	0.4	0	
Fathead minnow	18	72	VEON® 245	100F	40.2	0	3
	17	20	DED-WEED	>100	>72	50	8
		96		>100	>72	50	
(E) 2,4,5-T, Triethanolamine Salt							
Rainbow trout	13	24		5F	1.74	0	8
Bluegill	13	24		5F	1.74	0	4
Sea lamprey	13	24		5F	1.74	0	4
(F) 2,4,5-T, Oleic-1,3-propylenediamine Salt							
Bluegill	25	24	Decamine T	11	2.5	50	5
		48	Decamine T	10	2.9	50	5
(G) 2,4,5-T, Isopropyl Ester							
Bluegill	31	24			1.8	50	5
		48			1.7	50	5
(H) 2,4,5-T, Butyl Ester							
Rainbow trout	13	24		>5	>4.1	0*	4
Bluegill	13	24		>5	>4.1	0*	4
Sea lamprey	13	24		>5	>4.1	0*	4
(I) 2,4,5-T, Isooctyl Esters							
Fathead minnow	18	72	Tech	80	53.0	0	3
				100	66.7	P	
				100	>66.7	100	
Bluegill (small)	22-25	12 (days)	liquid	1.0	0.70	0	6
Green sunfish (fry)	22-25	24	liquid	4.0	2.78	0	8
Green sunfish (egg embryo)	22-25	72	liquid	4.0	2.78	0	8
Smallmouth bass	22-25	24	liquid	4.0	2.78	0	8
Bluegill (small)	22-25	12 (days)	granular	10.0	0.95	0	8
Bluegill (fry)	22-28	8 (days)	granular	10.0	6.98	0	8
Green sunfish (fry)	22-28	8 (days)	granular	10.0	6.98	0	8

Table 42 (con't.)

Species of fish	Water temp.°C	Hours exposure	Commercial Formulation Tested	Dosage (ppm) a.i.	Dosage (ppm) a.e.	% Mortality	Reference
Green sunfish (egg embryo)	22-25	72	granular (not Dow)	10.0	6.95	0	8
Bluegill	25	24	Chipman LVE-4L	41	21	50	7,8
		48	Chipman LVE-4L	41	31	50	7,8
		24	Chipman LVE-4L	40	28	50	7,8
		48	Chipman LVE-4L	37	26	50	7,8
		24	Hercules Brush Rhap LV-40	12	10.4	50	7,8
		48	Hercules Brush Rhap LV-40	15	10.4	50	7,8
(J) 2,4,5-T, Butoxyethanol Ester							
Bluegill	25	24	Weedone Clover Killer	2.2	1.4	50	7,8
		48	Weedone Clover Killer	2.0	1.4	50	7,8
Redear sunfish	24	24	50.9% a.i.	>1	<0.72	50	9
		24	50.9% a.i.	0.1-1.0	0.07-0.72	50	8
(K) 2,4,5-T, Propyleneglycol Butyl Ether Esters							
Bluegill	25	24	ESTERON* 245	28	17	50	1,8
		48		28	17	50	
Spot	10	24	Tech.	0.32	0.21	50	2
				0.32	0.21	50	
Fathead minnow	10	72	Tech.	1.0	0.65	0	2
				2.0	1.30	100	
Fathead minnow	10	72	ESTERON* 245 O.S.	0.75F	0.32	0	3
				1.0	0.44	P	
				2.0	0.88	100	
Fathead minnow	10	72	REDDON*	3.0F	2.4	0	3
				2.0F	2.27	P	
				1.5F	1.0	100	
Bluegill	24	7	REDDON*	0.2	0.12	100	10
				1.0F			
Bass	24	3.2	REDDON*	0.2	0.12	100	10
		3.2	REDDON*	1.0	0.63	100	
				2.0F			
Fathead minnow	24	48	REDDON*	0.2	0.13	100	10
		7	REDDON*	1.0	0.63	100	
		4	REDDON*	2.00	1.33	100	
				50.0F			
Rainbow trout	12	24	REDDON*	0.2	0.13	100	10
		2	REDDON*	1.0	0.63	100	
				5.0F			

[1] flowing salt water, otherwise fresh water

[2] underlined dosage data is that quoted from the literature. Other dosage data calculated

[3] Derived LC50 includes all 50% mortality data in the table

a.e. = acid equivalent

a.i. = active ingredient

F = Formulation

*Data needs confirmation

Table 43. Lethal concentrations (LC_{50}) at which 50% of the fish are killed when treated with the various herbicides used to control mesquite (Pimmental, 1971).

	Dicamba		Diuron		Fenuron		Monuron		Picloram		Silvex		2,4,5-T		Tebuthiuron	
Fish	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}
Coho Salmon (juvenile)		151ppm		16ppm												
Rainbow Trout (24-hr)										150 to 230ppm		23ppm		12ppm		
Rainbow Trout (48-hr)		35ppm		60ppm 4300ppb						2.5ppm		0.65ppm		1.3ppm		
Bluegills (24-hr)		130ppm		Resistant 9700 to 27000ppb		>10.0ppm		>10.0ppm				2.9 to 70ppm		1.8 to 53.7ppm		
Bluegills (48-hr)												0.6 to 1.4ppm		0.5 to 16.7ppm		
Largemouth Bass (48-hr)				42ppm												
White crappie				<6ppm												
Striped bass (96-hr)				3.1ppm												
Spot (48-hr)						>1.0ppm						0.36ppm				
Green sunfish (24-hr)						>10.0ppm		>10.0ppm		150 to 420ppm						
Lake Chub-sucker						>10.0ppm		>10.0ppm								
Smallmouth bass						>10.0ppm		>10.0ppm								
Golden shiners								~20.0ppm								
Channel catfish (24-hr)								75.9ppm								
Mullet (48-hr)								16.3ppm						50ppm		
Salmon (48-hr)								110.3ppm				1.23ppm				
Fathead minnow (24-hr)								64 to 135ppm				8.9ppm				
Harlequin fish (24-hr)								66ppm				48ppm		1.0ppm		
Brown trout (24-hr)								230 to 240ppm								
Brook trout (24-hr)								240 to 420ppm								
Black bullhead (24-hr)								420ppm								
Fish																>160mg/k

Table 44. Lethal concentrations (LC_{50}) at which 50% of the molluscs are killed when exposed to the various herbicides used to control mesquite (Pimmental, 1971).

	Dicamba		Diuron		Fenuron		Monuron		Picloram		Silvex		2,4,5-T	
Molluscs	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}
Eastern oysters (48-hr)				1.8ppm						>1ppm				
Oysters								~2.0ppm				~1.0ppm		>2.0ppm
Snails										380<530 ppm				

Grigsby, B. H. and E. D. Farwell. 1950. Some effects of herbicides on pasture and on grazing livestock. Mich. Quart. Bull. 32:378-385. (Titles unknown, Dep. Botany and Plant Pathology, and Animal Husbandry, Mich. State Univ., East Lansing, Mich.; research conducted in Mich.)

Results of this experiment indicate that none of the herbicides used had any serious physiological effect upon the livestock involved. They also indicate that none of the livestock preferred any of the sprayed areas to those that were unsprayed; however, with the lots sprayed with 2,4-D herbicides, the livestock grazed the sprayed areas almost as well as they did the unsprayed.

Since the rates used were 2 to 4 times greater than recommended dosage, it seems that farm use of these materials for pasture weed control is a reasonably safe procedure.

The organoleptic test indicates that further experiments should be conducted to test the effects of herbicidal applications on milk.

The use of dinitrophenol and pentachlorophenol, while causing temporary reduction of forage, will not destroy a pasture. The effects are more severe on legumes than they are on grasses.

TCA should be used in pastures only where complete destruction of forage can be tolerated. This use may be justified where patches of undesirable vegetation need control measures.

The use of 2,4-D in pastures is not injurious to stock. Such usage, however, will cause some reduction, and possible complete destruction, of legume forage plants. Spraying of patches of Canada thistle, bull thistle, burdock, and other broad-leaved pasture weeds should be done to prevent further spread of these weeds.

The effects of 2,4,5-T on forage plants were of the same order as those from 2,4-D applications. The known superiority of 2,4,5-T for the control of brush indicates that 2,4,5-T may be a more useful compound for pasture improvement work than 2,4-D.

Abelson, P. H. 1970. Pollution by organic chemicals. Science 170(3957): 495. (Credentials unknown).

A survey of efforts to secure a livable environment leaves one with the impression that progress is being made in a number of respects. One

Abelson 1970 (con't.)

area that has not received as much attention as it should is pollution by organic chemicals. Of particular concern should be the large group of molecules that are fat-soluble and only slowly biodegradable. Organic chemicals that are fat-soluble often tend to be accumulated in living systems. If not biodegradable, they may be concentrated by the food chain or other mechanisms so that their level in tissue comes to exceed that in the environment by orders of magnitude.

An example of a fat-soluble, slowly degradable compound is DDT. Its tendency to be accumulated by fish, birds, and humans has been repeatedly discussed. A large number of chlorinated aromatic hydrocarbons and chlorinated phenols and their derivatives are also concentrated in living forms. Many of these chemicals are known to have adverse biological effects. The most toxic chlorine-containing compound known is 2,3,7,8-tetrachlorodibenzodioxine ($C_{12}H_4O_2Cl_4$), often called dioxin. The acute oral LD_{50} dose of dioxin in male guinea pigs is about 10^{-6} g/kg. Other animal experiments have resulted in a variety of pathologic phenomena, including neurological disturbances and birth defects. Dioxin is an unwanted contaminant of the herbicide 2,4,5-T. When manufacture of the herbicide is carefully controlled, the dioxin content is less than 1 part per million. Higher concentrations have been noted, however. Dioxin was identified in 1962, after 5 years of dedicated research. In 1957, a mysterious disease had caused millions of dollars of damage and the death of uncounted numbers of chicks. Careful chemical detective work ultimately pointed to dioxin as the culprit. Apparently the herbicide 2,4,5-T or derivatives of it had been taken into plants and had ultimately appeared in vegetable oils. These were processed at high temperatures to liberate fatty acids, but inadvertently some dioxin, which has extreme thermal stability, was formed. Once the problem was identified, the chemical process was modified. Oddly enough, in spite of its great toxicity, the behavior of dioxin in the food chain has not been worked out.

The broad-scale and dramatic deleterious effects of dioxin was manifested in chicks. How much damage has this substance caused in humans? We know that all of us carry substantial quantities of DDT. How much damage has been caused by other related fat-soluble compounds?

When we use DDT and 2,4,5-T, presumably we obtain benefits that tend to balance, or even more than compensate for, the hazards attending them. Moreover, we can test the toxicity of manufacturers' products and be alert to possible problems. However, how do we cope with other possible dioxins? We are manufacturing thousands of chemicals. In their preparation, side reactions are producing many thousands of unwanted and even unidentified substances. To what extent are these strangers being discarded into rivers, lakes and the sea? To what extent are such substances finding their way into humans?

Companies producing fat-soluble, nonbiodegradable, organic chemicals should give careful attention to the question of what they may responsibly set loose on the environment. Failure to act now will surely lead to some new tragedy, aroused public opinion, and harsh federal regulations.

Norris, L. A. 1971. Chemical brush control: assessing the hazard.

J. Forest. 69:715-720. (Principal chemist, Forestry Sci. Lab.,

USDA-FS, Corvallis, Oregon; summary article).

An adequate evaluation of the hazard associated with the use of any chemical agent requires consideration of both the toxicity of the material and the potential for exposure of nontarget organisms. The hazard can be high only if both the toxicity of the chemical and the potential for exposure to a significant dose are high. The relatively large doses of 2,4-D, amitrole, 2,4,5-T, and picloram required to produce acutely toxic responses in most nontarget organisms are not likely to occur from normal chemical brush control operations on forest lands. The short persistence, lack of biomagnification in food chains, and the rapid excretion of these herbicides by animals preclude chronic exposure and, therefore, chronic toxicity. A long history of field use and research shows our common brush control chemicals can be used with minimum hazard to the quality of our environment.

Anon. 1972. No herbicide residues in meat. Agr. Res. 20(12):6-7.

(Credentials unknown; research conducted by USDA-ARS, College Station,

Texas).

Normal use of chemical weed and brush killers on rangelands appears to offer no problem of harmful residues in the meat of animals that graze these ranges.

Silvex, 2,4-D, and 2,4,5-T are chlorophenoxy herbicides registered for use in controlling broadleaf and woody plants--including mesquite on rangelands where sheep and cattle graze. Ranchers have been concerned that ingestion of herbicides from treated ranges could result in contamination of the meat, making it unfit for human consumption. However, ARS scientists have found that residue levels in the meat readily disappear.

Led by ARS chemist Donald E. Clark, College Station, Tex., a team of scientists conducted experiments in feeding silvex, 2,4-D, and 2,4,5-T to sheep and cattle.

The experimental animals, 32 cattle and 24 sheep, were fed 3 percent of their body weight in rations containing the various levels of the herbicides daily. The feeding program continued for 28 days.

Cattle were fed either silvex or 2,4-D at three levels--2,000, 1,000 and 300 parts per million (ppm). Feeding 300 ppm of these herbicides represents the normal level of feed contamination that could be expected after application of the pesticides to rangeland. However, this concentration would last for only a few days under natural conditions and as long as the 28 days in the experiment. The 2,000 and 1,000 ppm rates simulate levels resulting from gross negligence in applying herbicides.

Anon 1972 (con't.)

The scientists divided the sheep into four groups of six animals and fed them 2,000 ppm of either silvex, 2,4-D, or 2,4,5-T or kept them as controls.

Both cattle and sheep fed 2,000 ppm of herbicide were slaughtered in two groups--one 24 hr after the last feeding of the pesticide, and one 7 days later. Scientists analyzed tissues from all the animals independently for pesticide levels in ARS laboratories, a herbicide manufacturing company, and USDA's Agricultural Marketing Service.

They found significantly reduced herbicide levels of all three compounds after the 7-day withdrawal period. For example, cattle fed 2,000 ppm of the silvex and alughtered within 24 hr had residues of 1.0 ppm in the muscle, 3.8 ppm in the fat, 8.4 ppm in the liver, and 24.0 ppm in the kidney. By contrast, cattle fed at this level and slaughtered 7 days later had residues measuring 0.11 ppm in the muscle, 0.67 in the fat, 0.55 ppm in the liver and 1.13 ppm in the kidney.

When the cattle were fed 300 ppm silvex and slaughtered within 24 hr residues of 0.07 ppm in the muscle, 5.73 ppm in the liver and 22.40 ppm in the kidney were found.

Both cattle and sheep fed 2,4-D at the 2,000 ppm level had less than 1 ppm in all tissues, except for the kidneys, when slaughtered within 24 hr.

Scientists point out that before slaughter, most livestock are sent from the range to feedlots for an average finishing period of over 100 days. Left on ranches, there usually is a finishing period which livestock are exposed to the pesticides.

Davis, F. S. 1972. 2,4,5-T. Am. Inst. Chem. Engineering Symp. Series 69:269-278. (Executive vice-president, Phytox Corp., College Station, Texas; review article).

Man has utilized herbicides such as 2,4-D and 2,4,5-T for the past 25 years to construct synthetic ecosystems which presumably serve his purposes better. Against these beneficial effects, the possible ramifications of their use must be considered and weighed. They are not toxic to mammals at the dosages required for maintaining the synthetic ecosystems. The bulk of the evidence gathered to date suggests that the chlorophenoxy herbicides dissipate rapidly from soils where they serve as a carbon source for the microbial population. Plants metabolize or complex the compounds readily. If domestic animals or wildlife ingest forage containing these herbicides, the chemicals are largely excreted via the urine. The possibilities of biological magnification seem remote. In general, the net effect on the environment has been reflected in increased yields of desirable species for man's use.

Long, M. L. 1972. Residues in milk and meat and safety to livestock from the use of phenoxy herbicides in pasture and rangelands. Down to Earth 28(1):12-20. (Registration Specialist, The Dow Chemical Co., Midland, Mich.; research conducted by USDA and reported by an Industry Task Force on Phenoxy Herbicide Tolerances).

Residues of phenoxy compounds and of their respective phenolic moieties are not likely to occur in milk, meat, fat, or meat byproducts of cattle and sheep from agricultural use of these herbicides. Such residues would occur only under the unlikely circumstances when the animals are milked or slaughtered while actually ingesting freshly treated forage in pasture or rangeland treated at high rates of application. This conclusion is based on practical consideration of treatment rates, of dissipation of residues in forage and tissues, and of grazing restrictions on current labeling for these herbicides.

No harmful effect is likely to occur in livestock from grazing areas treated with phenoxy herbicides, even at exaggerated rates of application.

The studies discussed in this report were conducted with 2,4-D (2,4-dichlorophenoxyacetic acid), 2,4,5-T (2,4,5-trichlorophenoxyacetic acid), silvex (2-(2,4,5-trichlorophenoxy)propionic acid), and MCPA (2-methyl-4-chlorophenoxyacetic acid) in dairy and beef cattle and in sheep.

Washuettl, J. 1974. Pesticide in milk and milk products. Pestic. Abstr. 7(12):779-780. (Wien. Tieraerztl. Monatsschr. 61(2):44-51, 1974). (Title unknown, Aschergasse, Vienna, Austria; location where research conducted unknown).

Studies on the contamination of milk and milk products by pesticide residues and residue dynamics and metabolism are reviewed. Pesticide residues in milk may be due to the treatment of the animals with pesticides or to the animals' ingestion of pesticide-contaminated fodder. Residues of organochlorine pesticides and their metabolites (DDT, BHC, dieldrin, lindane, *p,p*'-DDT, *p,p*'-DDE, heptachlor epoxide, chlordane and its epoxy derivative) were found most often in milk; toxaphene and endosulfan were found occasionally. Organophosphorus pesticides, such as parathion, demeton, dimethoate, supracid (methidathion), fenchlorfos (ronnel), and trichlorfon, are excreted rapidly, as are carbamates, dalapon, 2,4-D, 2,4,5-T and triazines. Such pesticides are present in milk in trace concentrations only. Lindane gave a moldy aftertaste to milk, sour cream, and butter; DDT made milk sweetish. Most of the

Washuettl 1974 (con't.)

processes applied in dairy technology bring about reduction and redistribution of the pesticide residues in the milk products. Heptachlor and its epoxide tend to accumulate in skim milk after centrifugation. Dieldrin and lindane are believed to inhibit the metabolic activity of certain microorganisms including some *Streptococcus* species in milk products.

Begliomini, A., and A. Fravolini. 1975. Pesticide residues in animal feeds. IV. Chlorinated and phosphated pesticides in fish meals and in barley, corn and soybean flour of foreign origin. Pestic. Abstr. J. 8(7):441. 74-1536. (Arch. Vet. Ital. 24:183-190, 1973). (Title unknown, Perugia, Italy; location where research conducted unknown).

One hundred samples of foreign-produced animal feeds were analyzed in order to determine the pesticide contamination level. Tests were carried out on 25 fish meals (Chile, Peru, Denmark); 25 soybean meals (USA, Brazil, Argentina); 25 samples of corn meal (USA, Argentina, Canada, Brazil); and 25 samples of barley flour (USA, Canada). This investigation involved BHC, lindane, heptachlor, aldrin, heptachlor epoxide, o,p'-DDE, p,p'-DDE, p,p'-DDD, o,p'-DDT, p,p'-DDT, methoxychlor, methyl parathion, parathion, n-butylester of 2,4,5-T, n-butylester of 2,4-D, isobutylester of 2,4-D, dieldrin, and endrin. All were analyzed by gas chromatography. Percentages and quantities in relation to the country of origin are reported.

Young, A. L., C. E. Thalken, and W. E. Ward. 1975. Vegetative assessment of test area C-52A, p. 11-27. In, Studies of the ecological impact of repetitive aerial applications of herbicides on the ecosystem of test area C-52A, Eglin AFB, Florida. Final Report ending December, 1974. AFAIL-TR-75-142 (Air Force Armament Laboratory. Eglin Air Force Base, Florida). (Captain (Ph.D.), Major (V.C.), and Lt. Col. (Ph.D.) of USAF, respectively; study area Eglin AFB, Florida).

In 1962, the Armament Development and Test Center, Eglin Air Force Base, Florida, was tasked with the responsibility for designing, developing, and testing aerial dissemination systems in support of military defoliation operations in Southeast Asia. It was necessary for this equipment to be tested under controlled conditions that were as near to being realistic as possible. For this purpose an elaborate testing installation, designed to measure deposition parameters, was established on the Eglin Reservation with the place of direct aerial application restricted to a highly instrumented area within Test Area C-52A (TA C-52A) in the southeastern part of the Reservation.

A total of 346,117 lb of herbicides were applied through repetitive aerial applications, over a period of 8 years (1962-1970), to an area of approximately 1 mi^2. The active ingredients of the four military herbicides (Orange, Purple, White, and Blue) sprayed on TA C-52A were 2,4-dichlorophenoxyacetic acid (2,4-D), 2,4,5-trichlorophenoxy-acetic acid (2,4,5-T), 4-amino-3,5,6-trichloropicolinic acid (picloram), and dimethylarsinic acid (cacodylic acid). It was apparent from analysis of remaining Orange herbicide samples and test grid soils that the 2,4,5-T herbicide contained significant levels of the highly teratogenic (fetus deforming) contaminant 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). In particular, one 92-acre test grid (Grid 1) used from 1962 through 1964 received 87,186 lb of 2,4,5-T. In 1974, analysis of 6-inch soil cores for TCDD taken at six locations in this area, indicated wide fluctuations in TCDD concentrations. The results for the uniformily mixed top 6-inch soil cores were 10, 25, 70, 110 and 710 parts per trillion (ppt) TCDD. Further analysis of a duplicate core, obtained from the site having 110 ppt TCDD concentration indicated that TCDD was stratified within the top 6 inches of soil. The analysis for depths of 0 to 1, 1 to 2, 2 to 4, and 4 to 6 inches resulted in detectable levels of 150, 160, 700 and 44 ppt TCDD, respectively. Thus significant levels of TCDD residue were found 10 years after the last herbicide mission on this grid.

This report documents the quantitative changes that have occurred in the vegetative and insect communities with ecological succession. In addition, detailed chemical and histopathological studies of segments of the rodent and reptile populations from the test site containing significant levels of TCDD in soil (Grid 1) are reported. Species diversity and food chain studies of the aquatic ecosystems assocated with TA C-52A are evaluated.

Because of the massive quantities of herbicides applied to TA C-52A, a unique opportunity existed to evaluate changes in vegetative patterns and/or succession. Field data suggested that climatic factors rather than herbicide residue influenced vegetative establishment especially on the southern portion of the test area, e.g., on or near Grid 1. When wind and temperature data, collected from 1963 to 1969, were combined with data on seed dispersal and regeneration potential, it became apparent that unfavorable conditions on the southern portion of the test area existed at the time when seed dispersal and establishment occurred. Nevertheless, when establishment did take place, a definite sequence in plant succession could be documented. The large seed grasses *Panicum virgatum*, switchgrass, and *Panicum lanuginosum*, woolly panicum, were the first perennial species to assume dominance. The annual herbs *Diodia teres*, rough buttonweed, and *Hypericum gentianoides*, poverty weed, rapidly spread in the loose soil around and between the dominant grasses. With time, other grasses occupied significant vegetative cover, especially *Andropogon virginicus*, broomsedge, and *Eragrostis refracta*, coastal lovegrass. The square foot transect

Young et al. 1975 (con't.)

method of analysis indicated that areas having 5 to 20% vegetative cover generally contained 14 species (8 grasses, 6 herbs) while an area of 80 to 100% vegetative cover generally contained 28 species (8 grasses, 20 herbs). Similarity between seeds most frequently found in rodent burrows and those from species shown to be early dominants in the plant community suggested that rodents may act as biological dispersal agents into areas of low vegetative cover.

Extensive animal studies were conducted during the summer of 1974. Several methods and procedures were used for collecting data on six interrelated parameters. These included extensive histopathologic examination of beach mouse (*Peromyscus polionutus*) tissues, a study of beach mouse burrow construction and diet, TCDD analysis of mouse liver tissue and pelts, an examination of the soil profile for potential zoning of TCDD, a laboratory experiment to demonstrate one possible route of TCDD uptake by the beach mouse, and an analysis of reptile tissue for TCDD contamination.

A total of 106 adults and 67 fetuses of beach mice were examined grossly and histologically for congenital and teratogenic defects. In general, microscopic examination of all tissues showed only minor and insignificant lesions of the type normally observed when a large group of animals are examined. The only exceptions being two mice with necrotizing hepatitis and one mouse with renal ectasia of one kidney. The hepatitis was considered to be viral induced and the renal ectasia was interpreted as being of little functional significance and probably a result of a unilateral congenital anomaly not related to any toxicity. An analysis of variance of liver and spleen weights indicated significant differences between control and TCDD-exposed animals. However, these differences were not explained by an histologic differences.

Samples of liver and pelts from mice captured in areas in which significant soil levels of TCDD were found, exhibited accumulations of TCDD in the liver from 540 to 1300 ppt, while pelt contamination was found to be 130 to 140 ppt.

A study of the beach mouse burrows and diet, combined with the findings that TCDD was confined to the top 6 inches of soil, suggested that a possible method of exposure to TCDD might be through soil contamination of the pelt during burrowing and movement of the animal through these burrows followed by subsequent ingestion of soil particles through grooming. The beach mouse was observed in the laboratory to spend much of its active period grooming. Thus, a laboratory study was conducted using alumina gel with and without 2.5 ppb TCDD to dust the pelts of test and control mice. This study confirmed 45 to 89 ppt were found on the pelts and a level of 125 ppt was found in liver tissues.

Young et al. 1975 (con't.)

The racerunner, *Cnemidophorus sexlineatus*, the most prevalent reptile on the grid, was also trapped and examined for gross defects as well as having tissue samples analyzed for TCDD residue. Significant levels of TCDD were found in the visceral mass (360 ppt) and the trunk (370 ppt) of reptiles collected from areas where soil levels of TCDD were the highest (Grid 1). These reptiles, however, showed no significant lesions or variations in visceral mass between control specimens and those collected from the contaminated sites.

A 1973 sweep net survey of the arthropods of the 1 mi^2 test area resulted in the collection of 5966 specimens belonging to 71 insect families and two arachnid orders. These totals represent the collections from five paired sweeps taken over a 1 mi section of test grid. A similar study performed in 1971 produced 1796 specimens, representing 70 insect families and one arachnid order, from five paired sweeps of the same area using the same basic sampling techniques. A much greater number of small to minute insects were taken in the 1973 study. Vegetative coverage of the test area had significantly increased since the 1971 study. Comparison of the results of the two studies also showed significant increases in the number of arthropod specimens and varieties per sampled grid transect, but there was little overall change in calculated community diversity. These results are not unexpected, and the population increases will continue as the test area stabilizes and develops further plant cover, thus allowing a succession of animal populations to invade the recovering habitat.

Species diversity studies were conducted in two aquatic ecosystems associated with TA C-52A (Trout and Mullet Creeks), while food chain studies were conducted only in one stream (Trout Creek) and a grid pond. Both the latter two locations were shown in 1973 to contain TCDD in silt. Since TCDD was not water soluble, a different route of entry into these aquatic systems was sought. Examination revealed that erosion of soil occurred into the pond on the test area and into the bayhead of Trout Creek immediately adjacent to Grid 1. TCDD levels of 10 to 35 ppt were found in silt of the aquatic systems, but only at the point where eroded soil entered the water. Species diversity studies of the stream were conducted in 1969, 1970, 1973, and 1974. Insect larvae, snails, diving beetles, crayfish, tadpoles, and major fish species from both aquatic systems were analyzed for TCDD. Species diversity studies indicated no significant change in the composition of ichthyofauna between these dates or a control stream. Concentrations of TCDD (12 ppt) were found in only two species of fish from the stream, *Hotropis hypselopterus*, sailfin shiner, and *Gambusia affinis*, mosquitofish. The sample of mosquitofish consisted of bodies with heads and tails removed. The samples of sailfin shiners were analyzed; on containing viscera only and the other bodies less heads, viscera, and caudal fins. Only the viscera contained TCDD. Samples of skin, muscle, gonads, and gut were obtained from *Lepomis punctatus*, spotted sunfish, from the test grid pond. Levels of TCDD in those body parts were 4, 4, 18, and 85 ppt, respectively. Gross pathological observations of the sunfish revealed no significant lesions or abnormalities.

Anon. 1976. Joint opinion of the Biologische Bundesantalt Braunschweig and the Federal Department of Health in Berlin concerning application of herbicides in forests. Pestic. Abstr. 9(2):71. 76-0307. (Allg. Forstz. 30:976-978). (Credentials unknown).

A joint statement by the Federal Institute of Biology in Braunschweig and the Federal Department of Health in Berlin is presented concerning the use and hazards of phenoxycarboxylic acid-derived herbicides in forests. The aerial distribution of such herbicides is permissible and is even recommended in view of increased uniformity of application and reduced poisoning risks for the operator as compared with conventional methods of application. Herbicides containing 2,4,5-T should be used in water collection areas only if the flow time of the water before capture is longer than 50 days. If applied according to the instructions, such herbicides present no threat to honeybees. Nectar and honey samples collected from 2,4,5-T-treated areas contained residues at a detection limit of 0.005 ppm. Experiments on laboratory, domestic, and game animals seem not to indicate any hazards from growth-regulating compounds if applied according to ingrowth-regulating compounds if applied according to instructions. It was not possible to confirm certain experimental results indicating embryotoxic effects of 2,4-D in fowl. The teratogenic dose of 2,4,5-T has been determined as 20 mg/kg/day; thus this pesticide presents no teratogenic threat to humans. On the other hand, the dioxin content in 2,4,5-T can be limited to 0.1 ppm. There are no indications of mutagenic hazards due to 2,4,5-T, and it should be added before flowering after the berries are harvested.

Young, A. L., P. J. Lehn, and M. F. Metee. 1976. Absence of TCDD toxicity in an aquatic ecosystem. Weed Sci. Soc. Am., Proc. (Abstract). (Titles unknown, Dep. Chem. and Physiology, USAF Academy, Colorado, Bloomsbury, N.J., and Northport, Ala., respectively; location where research conducted unknown).

Species diversities and food chain studies were conducted in two aquatic ecosystems draining a unique 1 mi^2 military test area that received 160,948 lb 2,4,5-T and 169,292 lb 2,4-D herbicide during the period 1962 to 1970. Significant levels (10 to 710 parts per trillion (ppt) 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) were found within the top 6 inches of the test area soil. Erosion of soil occurred into a pond on the test area and into a stream immediately adjacent to the area. TCDD levels of 10 to 35 ppt were found in silt of the aquatic systems, but only at the point where eroded soil entered the water. Species diversity studies of the stream were conducted in

Young et al. 1976 (con't.)

1969, 1970, 1973 and 1974. Insect larvae, snails, diving beetles, crayfish, tadpoles, and major fish species (by body parts) from both aquatic systems were analyzed for TCDD. Species diversity studies indicated no significant change in the composition of ichthyofauna between these dates or a control stream. Concentrations of TCDD (12 ppt) were found in only two species of fish from the stream, *Notropis hypsclopterus*, Gunther (sailfin shiner), and *Gambusia affinis*, Baird and Girard (Mosquitofish). The sample of mosquitofish consisted of bodies with heads and tails removed. Two samples of sailfin shiner were analyzed; one containing viscera only and the other bodies less heads, viscera, and caudal fins. Only the viscera contained TCDD. Samples of skin, muscle, gonads, and gut were obtained from *Lepomis punctatus*. Valenciennes (spotted sunfish), from the test grid pond. Levels of TCDD in those body parts were 4, 4, 18 and 85 ppt, respectively. Gross pathological observations of the sunfish revealed no significant lesions or abnormalities.

Wellenstein, G. 1976. Biological and eco-toxicological problems regarding aerial application of phenoxyacetic acid derivatives in forests. Pestic. Abstr. 9(7):490. 76-1645. (Qual. Plant. Pl. Foods Hum. Nutri. 25:1-20, 1975). (Title unknown, Lettenweg, Germany; research conducted in Germany).

The importance of forests in the production of berries, mushrooms, nectar, and venison is demonstrated and the contamination of these foods by chemicals is proven. The planning and execution of chemical pest control therefore demands more attention to the recommendations of biologists and physicians. In this respect, control measures which have been used since 1970 on almost 8000 ha of German forest land are unsatisfactory. The effects of 2,4,5-T formulations on forest ecosystems are described, and results are given from residue analyses and nitrate determinations in 26 plant species. The unexpectedly high residual concentrations of slowly degraded herbicides present an acute danger to humans gathering berries and mushrooms, as well as to phytophagous animals. Growth regulating herbicides are also highly toxic to the honey bee acting as both stomach and contact poisons. The application, particularly the aerial application, of such herbicides in the forest should be generally prohibited.

Eijsackers, H. 1975. Effects of the herbicide 2,4,5-T on Onychiurus quadriocellatus Grisin (Coll.). Prog. in Soil Zool., Fifth Inter. Colloquium, Proc. 5:481-488. (Title unknown, Research Inst. for Nature Management, Arnhem; location where research conducted unknown).

The herbicide 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), a representative of the hormone herbicides, is used in coniferous forests in the Netherlands to control the black cherry. This species, which was imported from Northern America and planted in our forests mainly because it was thought to improve soil conditions, gradually became dominant in many coniferous forests and in addition a number of deciduous stands with value from the point of view of nature conservancy were also invaded, interesting undergrowth being replaced by a uniform black cherry vegetation.

Therefore control became necessary. This can be accomplished mechanically or chemically. Mechanical control, i.e., cutting of the shrubs, is inefficient, because the rapid and vigorous regrowth makes regular repetition necessary and this is too expensive. Chemical control can be accomplished by spraying the leaves with a 3% aqueous solution of 2,4,5-T or by smearing the stems with a mixture of the herbicide and fuel oil (the herbicide contained 40% a.i.). Especially with a watery spray, a considerable amount of herbicide reaches the forest floor. We estimated that under field conditions between 3 and 10 litres of 2,4,5-T/ha can drip from the leaves onto the forest floor. This contamination caused some concern because of the possible side-effects of 2,4,5-T on the soil fauna, particularly in view of the alarming information about the teratogenic effect of 2,4,5-T.

III. Pollution and Toxic Hazards
A. Toxicity to Non-Target Organisms
6. Food Chain

SUMMARY AND CONCLUSIONS

One of the major concerns that eminates from the use of all pesticides is biomagnification in the food chain. Yet there are relatively few studies that have been reported on movement of dioxin or of any of the herbicides used to control mesquite through the food chain. There remains an element of emotionalism about spraying mesquite and its ultimate effect upon both target and non-target organisms as well as the environment (e.g. Eijsackers, 1975).

In reality, most research has demonstrated that herbicides used in mesquite control, particularly 2,4,5-T, do not move through the food chain, at least at a hazardous concentration (Davis, 1972). Norris (1971) indicated that 2,4,5-T and picloram, applied at recommended commercial rates, are not present in sufficient concentrations to cause toxic effects on non-target organisms. He also indicated that they are rapidly excreted by animals if they become ingested. Research conducted by USDA-ARS in College Station revealed that meat from cattle fed 2,4,5-T and silvex treated rations (at rates commercially applied to control mesquite) contained less than 1.0 ppm, or less when the animals were slaughtered within 24 hr after eating treated foodstuffs (Anon., 1972). If cattle were slaughtered 7 days after treatment, residues in the meat were substantially reduced. Residues from all herbicides tested were higher in the liver and kidneys than in the muscle. Similar results were reported by Long (1972). Since 2,4,5-T is rapidly excreted by cattle, there aren't any residues that appear in milk (Washuettl, 1974).

Wellenstein (1976) reported that uses of 2,4,5-T to control black cherry in Germany could cause deleterious effects to honey bees of the area and to humans gathering berries and mushrooms in the forest. However, a joint opinion from the Federal Institute of Biology in Braunschweig and the Federal Department of Health in Berlin, Germany, indicated there were no hazards to laboratory, domestic, or game animals, honey bees or humans if 2,4,5-T is applied according to instructions (Anon., 1976).

The issue is not settled but it appears that scientific evidence does not support biomagnification through food chains of herbicides used to control mesquite.

Baskin, A. D. and E. A. Walker. 1954. The response of tomato plants to vapors of 2,4-D and/or 2,4,5-T formulations at normal and higher temperatures. Weeds 2:280-287. (Pathologists, USDA-ARS; location where research conducted unknown).

Compared with the check and controls used in all the tests made, amine formulations appeared to be low volatile at temperatures of 90° to 120° F. The lower alkyl esters (isopropyl, butyl, alkyl, amyl, and/or pentyl) have been found to be volatile at normal temperatures. The initial responses of tomato plants to the butyl ester formulation were intensified as the temperature was raised from 70° F to 90° F and 120° F and the accumulated effect was not mitigated 72 hr after exposure. Some of the higher molecular weight esters although low in volatility at 70° F caused formative responses in tomato plants at 90° F while others (propylene glycol, and tetrahydrofurfuryl) continued to be low in volatility at 90° F, but were volatile when the temperature was raised to 120° F.

This is in agreement with the findings of others who concluded from their tests that physiological activity of 2,4-D and 2,4,5-T ester herbicides increased as temperature and duration of exposure were increased.

The concept of theshold concentrations for vapors of any one group of esters containing widely different amounts of the active acids appears reasonable in accounting for the similarity of formative effects obtained despite this variation, provided all concentrations are above a "Threshold."

Products similar to the propylene glycol and tetrahydrofurfuryl formulations found to be low volatile at 90° F might appear volatile in future tests. Past experience indicated that purity of the alcohol used for esterification might be an important factor. The amount of lower alkyl alcohols persisting as residues could, conceivably, form lower alkyl esters and thereby cause a formulation to be volatile at 90° F or even at normal temperature. It is also conceivable that commercial formulations may contain esters other than those designated in the labeling. Tests are now being made relative to these effects and will be reported when available.

Fletcher, W. W., P. B. Dickenson, J. D. Forest, and J. C. Raymond. 1957. The effect of soil applications of certain substituted phenoxyacetic and phenoxybutyric acids on the growth and nodulation of *Trifolium repens sylvestre*. Phyton 9:41-46. (Titles unknown, West of Scotland Agricultural College, Glasgow; research conducted in Scotland).

The effect of the sodium salts of certain substituted phenoxyacetic acids, 2,4-D (2:4-dichlorophenoxyacetic acid), MCPA (2-methyl-4-chlorophenoxyacetic acid) 2,4,5-T (2:4:5-trichlorophenoxyacetic acid) and substituted phenoxybutyric acids, 2,4-DB (γ-(2:4 dichlorophenoxy) butyric acid), MCPB (γ-(2-methyl-4-chlorophenoxy)butyric acid) was tested on the growth and nodulation of White Clover (*Trifolium repens sylvestre*) in soil culture under greenhouse conditions. In Experiment I the herbicides were added to the soil and the seeds of the clover then planted. In Experiment II the herbicides were applied to established young plants of clover to the foliage only and to the soil only. The results show that in the case of seeds germinating after application of the herbicide to the soil the relative toxicity of the herbicides depends upon the rate of their breakdown in the soil, 2,4,5-T being much more toxic than MCPA or 2,4-D because of its greater persistence in the soil.

It is shown that MCPB and 2,4-DB are relatively non-toxic compared with 2,4-D, MCPA and 2,4,5-T when applied to the foliage only. In soil applications, 2,4-DB is relatively non-toxic.

Decker, E. 1959. The use of herbicides in nature sanctuary management. Northeastern Weed Sci. Soc., Proc. 13:372-376. (Resident Director, Westmoreland Sanctuary, Mount Kisco, N. York; research conducted on Westmoreland Sanctuary).

The occurrence of unfortunate incidents involving the unwise choice of materials and the incorrect application of herbicides has caused many persons to regard the use of any chemical herbicide as a hazardous and unthinkable operation. Nevertheless, herbicides of the systemic hormone type have provided safe, efficient and economical tools for use in the management of a nature study sanctuary type operation.

Robinson, A. G. 1961. Effects of amitrole, zytron and other herbicides or plant growth regulators on the pea aphid, Acyrthosiphon pisum (Harris), caged on broad bean, Vicia faba L. Can. J. Plant Sci. 41:413-417. (Grad. Student, Dep. Entomology, Univ. Manitoba, Winnipeg, Manitoba).

Thirty herbicides or plant growth regulators were tested against the pea aphid, on broad bean. When amitrole at 300, 200 and 100 ppm a.i. in water was absorbed by the roots, fecundity of the adults was reduced and mortality of their progency was 100, 100 and 93.9% respectively. No significant effects on fecundity occurred when amitrole was applied to the leaves or as a contact spray on adult aphids. When Zytron at 3000, 2000 and 1000 ppm a.i. in water was absorbed by the roots, mortality of adults was 100, 100 and 95% and of their progency 100, 100 and 98%, respectively. When Zytron was applied to the leaves at 8000, 4000 and 2000 ppm a.i. in water there was a mortality of adults of 85, 70 and 50% and of nymphs 75.1, 45.4 and 29.9%. The lower mortality of numphs occurred over a 5-day period, indicating that the initial toxic effects from application to the leaves were soon lost. Mortality of nymphs refers to young aphids born alive and killed by the toxic effects of amitrole of Zytron. Twenty-seven of the chemicals showed no effects on aphids caged on treated plants.

Bocks, S. M., Jr., L. Smith and R. O. C. Norma. 1964. Hydroxylation of phenoxyacetic acid and anisole by *Aspergillus niger* (van Tiegh). Nature 207:398. (Titles unknown, Dyson Perrins Laboratory, South Parks Road, Oxford; location where research conducted unknown).

Investigations of the hydroxylating activity of *A. niger* have been carried out mainly in connection with the metabolism of the phenoxy- and naphthyloxy-alkyl-carboxylic acids, at least in part because of the importance of these compounds as herbicides. We have been examining the action of this organism, using van Tiegh strain, on various benzenoid compounds, and since our results for the hydroxylation of phenoxyacetic acid differ fundamentally from those obtained with van Tiegh (Mulder strain, we wish to report our findings for both this compound and the related aromatic ether, anisole.)

Bocks et al. 1964 (con't.)

A replacement culture technique was used with both substrates. The organism was grown on a glucose salt medium containing 1 % malt at 25° for 72 hr. The medium was then removed and the mycelium was washed and, in the case of phenoxyacetic acid, resuspended in a 0·001 M solution of the substrate at pH 8 (0·01 M phosphate buffer). After incubation for periods of 3, 5, and 7 days, carried out on a rotary shaker at 25°, the medium was analyzed for phenolic products. Because of anisole's insolubility and toxicity, the technique was slightly modified in this case: the substrate was dissolved in about seven times its volume of carbon tetrachloride and this solution was placed at the bottom of each culture flask.

The main product from phenoxyacetic acid was identical to 2-hydroxyphenoxyacetic acid in the following respects: (a) R_F 0·44 at room temperature, in butanolethanol-3M ammonia (4:1:5); (b) colour reactions with the detecting reagents ferric chloride-potassium ferricyanide (pink) and diazotized p-nitroaniline (yellow); (c) ultraviolet absorption (λ_{max}275 mμ at pH 2·0 and 288 mμ at pH 11·0); (d) retention time in gas chromatographic analysis on diethyleneglycol adipate polyester. Authentic 4-hydroxyphenoxyacetic acid had R_F=0·27, gave blue and red spots, respectively, with the two detecting reagents, and had λ_{max} 287 mμ at pH 2·0 and 306 mμ at pH 11·0, and material with these properties could not be detected in the extract. Gas chromatographic analysis revealed the presence of phenol as a minor product.

The product from anisole was found by paper chromotography to contain guaiacol (o-methoxyphenol), but the meta- and para-isomers were not detected. Gas chromatography on diethyleneglycol adipate polyester, using conditions in which phenol and the three methoxyphenols were completely resolved, showed that at least 95 % of the mono-hydroxylated product was the ortho-derivative, but the occurrence of very small peaks with retention times equal to those of the meta- and para-derivatives indicated that the possibility of their being present could not be entirely excluded. Gas chromatography also showed that phenol was present in almost as large a quantity as guaiacol when incubation was stopped after 3 days but in lower yield relative to guaiacol after 7 days. Reduction of the pH of the incubation medium from 8 to 7 lowered the yield of hydroxylated products, while at pH 6 no hydroxylation could be detected.

The reactions of these aromatic ethers indicate that an ortho-hydroxylase is produced by the organism. This is in contrast to the report that the van Tiegh (Mulder) strain is relatively non-specific in its hydroxylating activity towards phenoxyacetic acid, giving both ortho- and para-hydroxy derivatives with predominance of the latter. It appears that the difference arises from a difference in the strains used, and a further study of this, as well as of the enzymatic nature of the hydroxylating system, is in progress. Finally, it is interesting to note that O-de-alkylation occurs with both substrates, as it does also in the liver microsome hydroxylating system.

Clifford, D. R. and D. Woodcock. 1964. Metabolism of phenoxyacetic acid by *Aspergillus niger* van Tiegh. Nature 203:763. (Title unknown, Research Station, Univ. Bristol, Long Ashton, Bristol; research conducted at the Univ. Bristol).

A recent communication reported the isolation of o-hydroxyphenoxyacetic acid as the main acidic product from the metabolism of phenoxyacetic acid by *A. niger*, using a replacement culture technique. Since these findings contrasted with our earlier work in which both o- and p-hydroxyphenoxyacetic acids had been isolated, it was thought advisable to re-investigate the problem.

It has not been shown using both paper and thin-layer chromatography that while ortho-hydroxylation is predominant, all three hydroxyphenoxyacetic acids are in fact produced. While the m- and p-isomers have very similar R_F values in the three solvents used, their presence is clearly indicated by the characteristic colours of the diazo-coupled spots (m-isomer, bright yellow; p-isomer, salmon-pink). Exposure of the chromatogram to ammonia vapour changed the colour of the m-spot to magenta and that of the p-spot to bright blue. Furthermore, the relative positions of the spots are reversed in the two solvent systems used in the paper chromatographic examination.

Cultures of *A. niger* (Mulder strain, C.M.I. 31283) were grown in penicillin flasks and after 3 days the medium was replaced by a solution of phenoxyacetic acid (10^{-3}M) in aqueous disodium hydrogen phosphate (10^{-2}M). After 24 h at 26°, the substrate was poured off and concentrated in a cyclone evaporator, and the acidified concentrate continuously extracted with ether.

In a typical experiment, from 31 liters of fungal substrate initially containing 4·7 g phenoxyacetic acid, 3 g of sodium bicarbonate-soluble material was isolated. Separation was achieved by partition chromatography using silica gel as the supporting medium for the stationary aqueous phase which was buffered to pH 8, the mobile phase being n-butanol-chloroform (successfully 60:40, 70:30, 80:20). After elution of unidentified material (0·9 g) and unchanged phenoxyacetic acid (1·42 g), the monohydroxyphenoxyacetic acids followed in the order o-(0·4 g), m-(0·02 g) and p-(0·1 g), details of their identification being given in Table 1.

The difference between these findings and our earlier report may reflect an improved separation technique or it may be due to a strain difference in *A. niger*. The culture used in the earlier work was Mulder strain, which had been in use at Long Ashton for some years previously; current practice is to renew the inoculum at frequent intervals from the Commonwealth Mycological Institute. The general pattern of hydroxylation appears to be relatively non-specific--resembling the metabolism of 2- and 4-chlorophenoxyacetic acids, but contrasting with results obtained in the metabolism of 2-naphthyloxyacetic acid and with recent results obtained with 2,4-dichlorophenoxyacetic acid.

Pimental, D. 1971. Ecological effects of pesticides on non-target species. Exec. Office of President. Gov. Printing Office. 220p. (Title unknown; summary of published reports).

Berkus, V. L. and L. W. Storm. 1973. Preliminary report on the effects of 2,4,5-T on *Drosophila melanogaster*. J. Ariz. Acad. Sci. 8 (supple):6. (Titles unknown, Univ. Nevada, Las Vegas; research conducted at the Univ. Nev., Las Vegas).

The large-scale application of 2,4,5-trichlorophenoxyacetic acid for defoliation in land management here and abroad poses some possibly unique hazards to all forms of wildlife. In examining the toxicity of 2,4,5-T, an experiment was designed to test the effects of the chemical on *Drosophila melanogaster*, the common fruit fly. Varying amounts of 2,4,5-T were thoroughly mixed with constant amounts of distilled water and specially prepared media. Exact numbers of live flies were introduced into these containers and an attempt was made to eliminate any factors which would effect the results. Controls were set up and mortality rates were recorded through the various stages in the life cycle.

Moffett, J. O. and H. L. Morton. 1973. Surfactants in water drown honey bees. Environ. Entomol. 2:227-231. (Research Entomologist and Plant Physiologist, respectively, USDA-ARS, Tucson, Ariz.; research conducted in southern Arizona).

Apis mellifera L. drowned in water containing as little as 25 ppmv of Multi-Film X-77^{R}, and higher concentrations (100 ppmv and above) caused very heavy losses. Yet, X-77 and 6 other surfactants (Brij^{R} 30, Brij^{R} 92, dimethyl sulfoxide, Span^{R} 20, Tween^{R} 20, and XF-1-3655 (nonionic water soluble silicone-glycol copolymer)) were relatively nontoxic to the bees as stomach poisons. Drowning occurred when the X-77 water was supplied in plastic buckets, dirt ponds, and cement ditches. The bees preferred water without X-77 to water containing X-77 by more than a 10 to 1 margin when given a free choice on drip boards or in cement ponds.

Moffett and Morton 1973 (con't.)

X-77 retained sufficient activity to drown bees in cement ponds for more than 60 days after it was added at 500 ppmv to the water.

During hot weather in June, July, and August, 1971, caged colonies with X-77 added to their water supply quickly ceased rearing brood, and all unsealed larvae died and some of the colonies died. Yet colonies receiving the same treatment during cooler weather did not suffer any observable damage although there was a continuous and heavy loss of water carriers.

Surfactants in small ponds, puddles, or irrigation ditches could cause bee losses. Given free choice, bees preferred water without X-77, but collected large quantities of water containing surfactant when confined to cages or when in apiaries with no other water source available.

Baluja, G., J. M. Franco, M. A. Murado. 1974. Interference of phenoxyacetic acid derivatives in the estimation of monochloroacetic acid by the thioindigo method. Pestic. Abstr. 7(5):326. 74-1250. (Arch. Environ. Contam. Toxicol. 1:375-380, 1973). (Titles unknown, Inst. of Organic Chemistry, Mardid, Spain; research conducted in Spain).

The thioindigo test, used for analysis of monohaloacetic acids in wines or preserved food, is based on reaction of thiosalicylic acid with the monohaloacetic acids in an alkaline medium at 100°C. After another heating at 200° C, the residue is oxidized with potassium ferricyanide to convert the thioindoxy intermediate to thioindigo which is measured spectrophotometrically at 550 nm. When this method was applied to estuarine sediments and mussels, the thioindigo color was obtained, although the presence of monochloroacetic acids in these specimens was unlikely. Purified samples of 2,4,5-T and its esters gave a color reaction in the thioindigo test, and the color formed was exponentially related to the amount of 2,4,5-T present in the solution. Thioindigo formation was attributed to cleavage of an acetate group from the herbicide under the energetic reaction conditions of the test. Due to their widespread use, phenoxyacetic acid herbicides may be present in many environmental samples, and therefore the thioindigo test cannot be applied as a specific method for monohaloacetic acid detection in such samples.

Fabacher, D. L. and H. Chambers. 1974. Resistence to herbicides in insect-resistent mosquitefish, *Gambusia affinis*. Environ. Letters 7(1):15-20. (Titles unknown, Dep. Entomology, Miss. State Univ., Miss.; research conducted at Miss. State).

The relative toxicities of 24 herbicides were determined for insecticide-susceptible mosquitofish. LC_{50} values were determined for three of the most toxic herbicides (DNBP, 2,4-D butyl ester, and trifluralin) to insecticide-susceptible and resistant mosquitofish to ascertain any differences in toxicity. Insecticide-resistant mosquitofish were found to possess a 1.87X resistance to 2,4-D butyl ester and a 2.05X resistance to trifluralin. This is apparently the first instance in which a species of fish has been shown to be resistant to herbicides.

Morton, H. L., J. O. Moffett, and R. D. Martin. 1974. Influence of water treated artificially with herbicides on honey bee colonies. Environ. Entomol. 3:80-812. (Plant Physiologist, Research Entomologist, and Biological Lab Technician, respectively, USDA-ARS, Tucson, Arizona; research conducted on the Santa Rita Exp. Range, Ariz.).

Apis mellifera L. colonies were placed in isolated desert apiaries where their only source of water contained paraquat (concentration of 1000 parts per million active ingredient by weight (ppmw)). Large numbers of bees exposed to paraquat died immediately, and all were dead before the end of the 5th week. When colonies were similarly exposed to like amounts of 2,4,5-T, large numbers of bees drowned in the water because of the lower surface tension of the water, and production of brood was reduced below that of check colonies during the period the treated water was used and for 3 months thereafter; however, in the subsequent 9 months, production returned to normal.

Concentrations of 2,4,5-T in honey bees from colonies using water containing 2,4,5-T were as high as 148 ppmw, but this level dropped to about 5 ppmw as soon as the bees began using untreated water. Likewise, honey from colonies using water containing 2,4,5-T contained concentrations of 2,4,5-T as high as 50 ppmw; however, the concentration dropped to about 5.0 ppmw within 1 week after the bees began using untreated water. The last day when any 2,4,5-T was detected in honey bees and honey from treated colonies was 480 days after the experiment began. Wax from colonies using the treated water contained detectable amounts of 2,4,5-T 650 days after the study was initiated.

Andrilenas, P. A. 1975. Farmers' use of pesticides in 1971. . . extent of crop use. U.S. Dep. Agr. Agr. Econ. Rep. No. 268. Washington, D. C. 25p. (Title unknown, USDA-ERS; report compiled from Statistical Reporting Serv. survey).

Over half of all U.S. farmers use pesticides to control crop pests on about 50% of their cropland acres. In 1971, about 45% of the farmers growing crops used herbicides, 26% used insecticides, 6% used fungicides, 2% used nematocides, and 10% used other pesticides (including defoliants), desiccants, growth regulators, miticides, and rodenticides). Farmers treated 41% of cropland acres (not including pasture and rangeland) with herbicides, and 15% with insecticides, 2% with fungicides, less than 1% with nematocides, and about 1% with other pesticides.

Maguire, J. and N. Watkin. 1975. Carbonic anhydrase inhibition. Environ. Contam. Toxicol., Bull. 13:625-629. (Title unknown, Water Science Section, Dep. Environment, Ottawa, Ontario, Canada; research conducted in Canada).

Carbonic anhydrase (carbonate hydro-lyase, EC 4.2.1.1) is involved to some extent in a number of processes, among them the exchange of carbon dioxide in blood, the regulation of CO_2 levels in photosynthesis by land plants and algae, and the deposition of $CaCO_3$ in shells of mollusks and eggshells. It is thought that inhibition of carbonic anhydrase activity in certain organisms leads to inhibition of photosynthesis and to eggshell thinning, the latter being the subject of a good deal of interest. This enzyme is important in a number of different areas and it was of interest to test the inhibitory effectiveness of a number of different chemicals on its activity. We have found that the hydrolysis of p-nitrophenyl acetate by carbonic anhydrase is inactivated by certain heavy metal salts, that certain other heavy metal compounds and organomercurials inhibit carbonic anhydrase activity non-competitively, and that certain chlorinated insecticides, soluble in dioxane-water systems, are mild non-competitive inhibitors.

Young, A. L., C. E. Thalken, and W. E. Ward. 1975. Vegetative assessment of test area C-52A, p. 11-27. In, Studies of the ecological impact of repetitive aerial applications of herbicides on the ecosystem of test area C-52A, Eglin AFB, Florida. Final Report ending December, 1974. AFAIL-TR-75-142 (Air Force Armament Laboratory. Eglin Air Force Base, Florida). (Captain (Ph.D.), Major (V.C.), and Lt. Col. (Ph.D.) of USAF, respectively; study area Eglin AFB, Florida).

Field investigations were conducted on rodents, insects, aquatic organisms, and plant species associated with a unique 1 mi^2 military test site (Test Area C-52A, Eglin Air Force Base, Florida) that was sprayed with 160,948 lb 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) and 169,292 lb 2,4-dichlorophenoxyacetic acid (2,4-D). Although neither 2,4-D nor 2,4,5-T residues could be detected in the soils in 1973 or 1974, significant levels (10 to 710 parts per trillion-ppt) of the contaminant 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) were found within the top 6 inches of test site soils although in some instances 10 years had elapsed since the last aerial application of 2,4,5-T.

An in-depth study of the field effects of the herbicide and TCDD was conducted on populations of beach mice, *Peromyscus polionotus*, and hispid cotton rats, *Sigmodon hispidus*. Liver tissue from rodents inhabiting the test site contained 210 to 1,300 ppt TCDD. However, no gross or histological evidence of teratogenesis or toxicity was found in 122 adults and 87 fetuses. An analysis of variance of liver and spleen weights for the beach mouse indicated significant differences between control and TCDD-exposed animals. Analysis of plant seeds revealed no detectable levels of TCDD (minimum detection limit of 1 ppt TCDD). TCDD accumulation in liver tissue was thoughtto be associated with pelt contamination from burrowing and subsequent ingestion of soil particles via grooming.

Establishment and succession of plant species on areas denuded by repetitive applications of the herbicides were documented. Large seeded grasses (e.g., *Panicum lanuginosum* and *Panicum virgatum*) were the first species established on these sites. Annual herbs (e.g., *Diodia teres* and *Hypericum gentianoides*) rapidly invaded the low, moist areas between the grass plants. Seasonal trends in the weather components of wind, temperature, and precipitation were more influential in the reestablishment of vegetation than were herbicide residues.

Young et al. 1975 (con't.)

Comparison of the final results in a 1971 and 1973 sweep net survey of the test area indicated that a threefold increase in insects had occurred during the 2-year period. However, there was no change in the community diversity with time. Increase in number of species was correlated with increase in vegetation.

Species diversities and food chain studies were conducted in two aquatic ecosystems draining the test area. Erosion of soil occurred into a pond on the test area and into a stream immediately adjacent to the area. TCDD levels of 10 to 35 ppt were found in silt of the aquatic systems but only at the points where eroded soil entered the water. Species diversity studies of the stream were conducted in 1969, 1970, 1973, and 1974. Insect larvae, snails, diving beetles, crayfish, tadpoles, and major fish species (by body parts) from both aquatic systems were analyzed for TCDD. Species diversity studies indicated no significant change in the composition of ichthyofauna between these dates or a control stream. Concentrations of TCDD (12 ppt) were found in only two species of fish from the stream, *Notropis hypselopterus* (sailfin shiner) and *Gambusia affinis* (mosquitofish). Samples of skin, muscle, gonads, and gut were obtained from *Lepomis punctatus* (spotted sunfish) from the test grid pond. Levels of TCDD in those body parts were 4, 4, 18, and 85 ppt, respectively. Gross pathological observations of the sunfish revealed no significant lesions or abnormalities.

Tomkins, D. J. 1976. Effects of herbicides on wild plants at chromosomal, population, and community levels. Pestic. Abstr. 9(10):726. 76-2496. (Diss. Abstr. Int. B (12 Pt. 1):5925, 1976). (Grad. student, McGill Univ., Montreal, Quebec, Canada; research conducted in Canada).

Seven herbicide formulations, 2,4-D, picloram, picloram + 2,4-D, 2,4-D + 2,4,5-T, paraquat, simazine, and diuron, were applied in two plant communities of different successional age, and observations were made at monthly intervals over 3 years. Chromosomal abnormalities were found in many susceptbile species after exposure to some herbicide. Auxins produced sticky bridges (pseudochiasmata) and laggards in some species, whereas simazine and diuron caused extensive, but short-lived, fragmentation. Observations at the population level indicated that several biological factors, including the level of ploidy and monocot-dicot differences, were important in determining the sensitivity of 75 weed species. Community studies showed that broadcast spraying of herbicides can cause significant changes in species diversity and dominance. In general, the recently disturbed community was more sensitive to modification than the more mature community.

Crane, J. C., L. C. Erickson, and B. L. Brannaman. . 2,4,5-trichlorophenoxyacetic acid residues in apricot fruits. Am. Soc. Hort. Sci., Proc. 87:123-127.

Residues of 2,4,5-T in all parts of apricot fruits were determined by gas chromatography at intervals from the time of 2,4,5-T application until fruit maturity. On the basis of µg/fruit, 2,4,5-T increased in all parts except the integuments in which there was an initial increase, followed by a decrease as the fruits developed. The largest quantities of 2,4,5-T were found in the exocarp and mesocarp, followed in decreasing order by the embryo, endocarp, and integuments. On a ppm basis, however, 2,4,5-T decreased in the exocarp and mesocarp as influx of water, sugars and other substances occurred with growth. A dramatic increase in concentration of 2,4,5-T in the integuments accompanied the dehydration of these tissues as they developed. The presence of unaltered 2,4,5-T, detected in relatively high concentrations in the embryos at fruit maturity, affords an explanation for poor seed germination and the morphogenic abnormalities that have been reported to occur in seedlings grown from seed of treated fruits.

III. Pollutant and Toxic Hazards
A. Toxicity to Non-Target Organisms
7. Other

SUMMARY AND CONCLUSIONS

When one considers spraying mesquite, all components of the ecosystem must be taken into account. Yet there is little information on the effect of spraying mesquite on non-target organisms not included in the preceding sections. Perhaps one of the most obvious is the effect of practically all herbicides on cultivated species and fruit trees. The tomato plant is quite susceptible as reported by Baskin and Walker (1954). Apricot fruits are adversely affected by 2,4,5-T (Crane et al.). Many other could have been included here, but perhaps the two examples cited will suffice.

Organisms that often are not considered relative to herbicidal control of plants are soil microorganisms. Soil applied phenoxy herbicides adversely affected growth and nodulation of white clover, presumably related to herbicide degradation in the soil (Fletcher et al., 1957).

The herbicides apparently can serve as a carbon source some of the soil microorganisms such as *Aspergillus niger* (Bocks et al., 1964; Clifford and Woodcock, 1964). Pimmental (1971) reported lethal doses and lethal concentrations for a few microorganisms (Table 45).

Apparently 2,4,5-T is not harmful to bees as a stomach poison, but it reduces the surface tension of water sufficiently that the bees drowned (Morton et al., 1974). Similar results can be obtained when a surfactant is added to the bee's water (Moffett and Morton, 1973). As long as bees were exposed to water containing 2,4,5-T, their honey had a detectable amount of 2,4,5-T in it; however, when the bees were furnished water without 2,4,5-T, 2,4,5-T residues dropped significantly within 1 week.

Table 45. Lethal dose and lethal concentration of various herbicides on microorganisms (Pimmental, 1971).

Microorganisms	Monuron		Picloram		Silvex		2,4,5-T	
	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}
Nitrifying bacteria	1 to 5 lb/acre	>50 ppm		>100 ppm				
Aspergillus niger				> 50 ppm				
Streptomyces					>50 lb/acre		>50 lb/acre	
Azotobacter sp.								1500 to 2000 ppm

Honey bees and honey contained detectable 2,4,5-T residues for 450 days after treatment, whereas the wax contained detectable levels of 2,4,5-T for 650 days after treatment (Morton et al., 1974).

Arthropods and annelids respond differently to different herbicides (Pinmental, 1971), yet there is not much research dealing with herbicidal effects (Table 46). Likewise, there are only a few reports of effects of herbicides used to control mesquite on algae and other phytoplanktons (Table 47) and amphibians (Table 48).

Table 46. Lethal dose and lethal concentration of herbicides used to control mesquite on several arthropods and annelids (Pimmental, 1971).

Annelids and Arthropoda	Dicamba		Diuron		Monuron		Picloram		Silvex		2,4,5-T	
	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}
Amphipod (24-hr)		10,000ppb		0.70ppm		>20ppm		50,000ppb				
Amphipod (48-hr)		5,800ppb		0.38ppm				48,000ppb				
honey bees	3.6 ug/bee											
Stonefly (24-hr) (48-hr)				3.60ppm 2.80ppm								
Waterflea (48-hr)				1.40ppm						2,000ppb		
Isopods						>20ppm						
White shrimp (48-hr)						>1.0ppm						
Earthworms					<10 lb/acre	~50ppm						
Wireworms					<10 lb/acre							
Millipedes					<10 lb/acre							
Springtails					<10 lb/acre							
Mites					<10 lb/acre							
Stonefly (nymphs) (24-hr)								120ppm		5.6ppm		
Daphnia (24-hr)								380< 530ppm		100ppm		1.5ppm
Brown ahrimp (48-hr)								>1.0ppm		0.24ppm		>1.0ppm
Eucypris												0.5ppm
Hyallella												0.7ppm
Palaemoneta												1.2ppm
Amphiagrion												7.5ppm
Pachydiplax												8.0ppm
Tramea												8.0ppm
Chironomus												6.0ppm

Table 47. Lethal dose and lethal concentrations of herbicides used to control mesquite on a few low plants (Pimmental, 1971).

	Diuron		Monuron		Picloram		Silvex		2,4,5-T	
Phytoplankton	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}	LD_{50}	LC_{50}
Phytoplankton		1.0ppm		<1.0ppm				∿1.0ppm		>1.0ppm
Algae						>1.0ppm				

Table 48. Lethal concentration of silvex on two species of amphibians (Pimental, 1971).

Amphibians	Silvex LD50	Silvex LC50
Fowler's toad tadpoles (24-hr)		22ppm
Chorus frog tadpoles (24-hr)		20ppm

DeRose, H. R. 1946. Persistence of some plant growth-regulators when applied to the soil in herbicidal treatments. Bot. Gaz. 107:583-589. (Capt., A.U.S.; research conducted at Camp Detrick, Federick, Md.).

1. Greenhouse experiments for determining the leachability and persistence of 2,4-dichlorophenoxyacetic acid in soil have been described.

2. When a soil was contaminated with 2,4-dichlorophenoxyacetic acid and then leached, it was found that the compound was present in the leachate.

3. It was demonstrated that normal plants developed in a greenhouse soil 8 weeks after the latter had been treated with high rates of 2,4-D. Observations with respect to seed germination were similar. It may therefore be concluded that, under greenhouse conditions, this herbicide does not remain active in unleached soil for longer than 8 weeks.

4. In the field it was shown that 2,4-D did not persist in soil for more than 80 days after treatment, while isopropyl N-phenylcarbamate had apparently disappeared within 60 days after treatment.

5. A field comparison was made of the persistence of 2,4-D, 2-methyl-4-chlorophenoxyacetic acid, and isopropylphenylcarbamate applied at a heavy rate to the soil. It was found that, after 68 days the soil still contained enough 2-methyl-4-chlorophenoxyacetic acid to be toxic to soybeans. On the other hand, 68 days after the soil have been treated with 2,4-D or isopropylphenylcarbamate, there was practically a complete disappearance of the herbicides from the soil even when the compounds were applied at rates far above those likely to be used in practice.

6. 2,4,5-trichlorophenoxyacetic acid retains its herbicidal effectiveness in the soil for a longer period of time than does 2,4-D.

DeRose, H. R. and A. S. Newman. 1947. The comparison of persistence of certain plant growth-regulators when applied to soil. Soil Sci. Soc. Am., Proc. 12:222-226. (Capt., and Agronomist, respectively, Chemical Corps, Camp Detrick, Md.; research conducted at Camp Detrick, Md.).

DeRose and Newman 1947 (con't.)

1. Closely related plant growth-regulators differed in persistence in soil. Regardless of the rates used 2,4-dichlorophenoxyacetic acid persisted in soil under greenhouse conditions only 67 days. 2,4,5-trichlorophenoxyacetic acid when applied at the rate of 1 mg/lb pound of soil persisted 147 days after initial application and when employed at a higher rate persisted 11 months after application.

2. In the field, 2,4,5-T applied at the rates of 5 and 20 lb/acre was persistent 93 days after application, while 2,4-D and 2-methyl-4-chlorophenoxyacetic acid had disappeared more rapidly. The rate of application had little influence on the period of persistence.

3. The persistence of plant growth-regulators in the soil varied inversely with the soil temperature. Regardless of soil temperature, 2,4,5-T applied at one-half the rate of 2,4-D and 2-methyl-4-chlorophenoxyacetic acid persisted in soil for longer time.

4. As the soil moisture levels increased the plant growth-regulators disappeared from soil more rapidly. At low moisture levels all compounds tested were persistent.

5. The persistence of 2,4-D, 2,4,5-T, and 2-methyl-4-chlorophenoxyacetic acid in soil was mainly determined by soil microbial activity. These compounds persisted in autoclaved soil for longer periods of time than they did in soil not autoclaved.

Payne, M. G. and J. L. Fults. 1947. Some effects of ultraviolet light on 2,4-D and related compounds. Science 106(2741):37-39. (Titles unknown, Dep. of Chemistry, and Botany and Plant Pathology, respectively, Colorado Agr. Exp. Sta., Ft. Collins, Colo.; research conducted in Colorado).

The results of this study indicates that ultraviolet light of the range and intensity described, when transmitted by filter 51, can be used to activate 2,4-D, the sodium salt, the butyl ester, and 2-methyl-4-chlorophenoxyacetic acid. Comparative tests of the herbicidal effects of these chemicals activated with ultraviolet light and those of untreated chemicals are suggested.

It is recognized that, with the exception of 2,4-D, pure compounds were not used in this investigation. Possibly purified salts and esters might give different reactions than the impure commercial mixtures used. Had this work been done first on the purified compounds, the question of its action on commercially available herbicides would still have been unanswered, and this was the question of immediate importance.

Payne and Fults 1947 (con't.)

The results further suggest a possible explanation of the variable results secured from uniform trials of 2,4-D and similar compounds at different times and places. Since the amount of ultraviolet light reaching the earth varies with change in atmospheric conditions, altitude, and season of the year, the herbicidal effects might be expected to vary accordingly. Field tests designed to settle this question are suggested.

Audus, J. L. 1951. The biological detoxication of hormone herbicides in the soil. Plant and Soil 3(2):170-172. (Title unknown, Botany Dep., Bedford College, Univ. London, England; research conducted in England).

1. The results of experiments on the continuous perfusion of aerated solutions of the herbicides 2,4-D, MCPA and 2,4,5-T through garden soil indicate that the kinetics of their breakdown are essentially similar.

2. Three phases can be distinguished: (a) an immediate initial adsorption onto soil colloids amounting to 0.167 ± 0.035 mg/g dry soil, (b) a lag phase of varying duration in which there is little or no disappearance of herbicide, (c) a final phase of rapid complete detoxication. Such "enriched" soils detoxicate subsequent perfusions with the same herbicide molecule at a constant high rate. Enrichment times for 2,4-D, MCPA, and 2,4,5-T are roughly of the order or 14, 70 and 270 days, respectively.

3. This indirect evidence, from kinetics of detoxication, of the development of a bacterial flora adapted to herbicide breakdown, is strongly supported by experiments in which the detoxicating activity of such enriched soils was completely destroyed by low concentrations (0.01%) of the bacterial poison, sodium azide.

4. Attempts to isolate in pure culture the 2,4-D-decomposing organism were successful. Preliminary classification work relegates the organism to the "*Bacterium globiforme* group". Further confirmatory work is required.

5. Cross perfusion experiments in which 2,4-D enriched soil were perfused with MCPA and vice versa indicate that both can detoxicate the other analogue, although at a somewhat lower rate than the soil directly enriched with that analogue.

6. 2,4-D enriched soil will not detoxicate 2,4,5-T although some activity may be temporarily induced by an intermediate perfusion with MCPA.

Newman, A. S., J. R. Thomas, and R. L. Walker. 1952. Disappearance of 2,4-dichlorophenoxyacetic acid and 2,4,5-trichlorophenoxyacetic acid from soil. Soil Sci. Soc. Am., Proc. 16:21-24. (Soil scientist, Grad. Research Assist., Washington State College and Corporal, U.S. Army Reserve, respectively; research conducted at Camp Detrick, Frederick, MD).

2,4-D was incubated in the laboratory with different depths of Duffield silty clay loam, and its disappearance therefrom was determined by a cucumber root elongation test. The lag period before onset of decomposition and the time required for complete decomposition of 2,4-D increased with depth. The lag period varied from 14 days in the 0- to 6-inch sample to 42 days in the 18- to 21-inch sample. On retreatment with 2,4-D the differences among the depths were much smaller than with the original treatment.

Disappearance of 2,4-D and 2,4,5-T under field conditions was studied in plots treated with these compounds at rates of 0.0, 0.2, 1.0, and 2.5 g/yd^2 in 1949, and retreated with 1 g/yd^2 in 1950. 2,4,5-T persisted more than 19 weeks; its persistence was not influenced by previous treatment. The effective concentration of 2,4-D was reduced more rapidly in soils in which it had decomposed previously. This compound persisted 5 and 6 weeks, respectively, in plots which had and had not been treated previously. A substance which stimulated root elongation of cucumber was produced during the decomposition of 2,4-D.

Burschel, P. and V. H. Freed. 1959. The decomposition of herbicides in soils. Weeds 7:157-162. (Fulbright, Fellow at Oregon State Univ. and Assoc. Chemist, Dep. Agr. Chemistry, Oregon State Univ., Corvallis, Ore.; research conducted at Oregon State Univ.).

The foregoing presentation has been concerned with the measurement of the rate of breakdown of IPC, CIPC and amitrol in the soil at two different temperatures. The data presented appear to support the conclusion that the decomposition process behaves as a first order reaction. It is possible on this basis to apply the Arrhenius equation to calculate the heat of activation required for this breakdown. Such calculations have been made and values presented for the three herbicides studies.

Burschel and Freed 1959 (con't.)

A consequence of these findings is that it may be possible to utilize such information in estimating the length of residual life of herbicides under field conditions. Additional work is needed to ascertain whether there is variability of the heat of activation with moisture level and soil type. However, such data are readily obtained in this type of study and would provide a reasonable basis to guide weed workers in estimating the length of residual life of the various herbicides in the soil under varying conditions.

Alexander, M. and M. I. H. Aleem. 1961. Effect of chemical structure on microbial decomposition of aromatic herbicides. J. Agr. Food Chem. 9:44-47. (Titles unknown, Dep. Agronomy, Cornell Univ., New York; research conducted in N. York).

The effect of molecular structure on the persistence and microbial decomposition of phenoxyalkyl carboxylic acid herbicides, chlorophenols, and some related compounds is presented. The resistance of some aromatic herbicides or their derivatives to microbial degradation is governed by the position of the halogen on the aromatic nucleus and by the linkage and type of aliphatic side chain.

MacRae, I. C. and M. Alexander. 1965. Microbial degradation of selected herbicides in soil. J. Agr. Food Chem. 13:72-76. (Titles unknown, Dep. Agronomy, Cornell Univ., N. York; research conducted in N. York).

EPTC, amitrole, amiben, and ipazine are degraded by the microflora of soil. $C^{14}O_2$ was not released microbiologically from soil receiving tagged propazine, atrazine, or simazine. The susceptibility of chlorobenzoates to decomposition is related to the number of chlorines on the aromatic ring. A technique for determining the ability of a specific soil population acting on one aromatic herbicide to destroy a structually related compound is described, and the method is used to show that a 2,4-D-metabolizing microorganisms are inactive on monochlorobenzoates. The resistance of dichlorophenols to microbial destruction is associated with the presence of a chlorine in the position meta to the phenolic hydroxyl. Seed inoculation with a 4-(2,4-DB)-utilizing *Flavobacterium* protected alfalfa in sterile soil amended with the herbicide, but little protection was observed in nonsterile soil.

Merkle, M. G., R. W. Bovey, and F. S. Davis. 1967. Factors affecting the persistence of picloram in soil. Agron. J. 59:413-415. (Assoc. Prof., Texas A&M Univ., and Research Agronomist and Research Plant Physiologist, USDA-ARS, College Station, Texas; research conducted at College Station).

The effect of soil type, temperature and moisture on the persistence of 4-amino-3,5,6-trichloropicolinic acid (picloram) was determined using vapor phase chromatographic analyses and plant bioassays. Detectable quantities of picloram were present in Houston clay, Axtell sandy loam, and commercial sand after incubation for 1 year, at 4, 20, and 38 C and at moisture levels of field capacity and 0.1 field capacity from rates as low as 0.25 μg/g (1/2 lb/acre). Movement studies indicated that leaching was an important means of dissipating the herbicide in light soils. Photodecomposition may also be important if the herbicide remains on the soil surface for long periods of time.

Baur, J. R., R. W. Bovey, and J. D. Smith. 1969. Herbicide concentrations in live oak treated with mixtures of picloram and 2,4,5-T. Weed Sci. 17:567-570. (Plant Physiologist and Agronomist, USDA-ARS, College Station, Texas A&M Univ.; research conducted near Victoria, Tx.).

Recovery of (2,4,5-trichlorophenoxy) acetic acid (2,4,5-T), as the acid and ester, was significantly greater in live oak (*Quercus virginiana* Mill.) tissues treated with mixtures of the 2-ethylexyl ester of 2,4,5-T (2 lb/acre):potassium salt or isooctyl ester of 4-amino-3,5,6-trichloropicolinic acid (picloram) (½, 1 and 2 lb/acre) than in tissues treated with 2 lb/acre 2,4,5-T ester alone. Recovery of 2,4,5-T as the ester was noted in the middle and lower-stem tissues. Between 90 and 99% of the herbicide recovered 1 month after treatment was gone 6 months after treatment. Evaluation of brush reduction 2 years after treatment indicated that mixtures of picloram salt and 2,4,5-T resulted in greater reduction of brush than mixtures of picloram ester and 2,4,5-T or 2,4,5-T alone.

Bovey, R. W. and C. J. Scifres. 1971. Residual characteristics of picloram in grassland ecosystems. Texas Agr. Exp. Sta. Bull. B-1111. Texas A&M Univ., College Station, Texas. 24p. (Research Agronomist, USDA-ARS, College Station and Assist. Prof., Dep. Range Science, Texas A&M Univ.;

Bovey and Scifres 1971 (con't.)
literature review).

Picloram, applied alone or in combination with 2,4,5-T, has potential for control of many species of herbaceous weeds and woody plants on grasslands. Picloram is relatively persistent, and complex factors influence the rate of dissipation from various segments of the ecosystem. Its persistent nature is one quality responsible for its effectiveness as an herbicide. Little data are available concerning the mode or degree of loss of picloram from the time it leaves the spray boom until it reaches the target areas. However, once picloram reaches plant and soil surfaces, there is progressive decline within the ecosystem. It is susceptible to photodecomposition. Picloram is mobile within the ecosystem and follows the movement of water.

Theoretically, picloram reaching the soil surface, if not photodecomposed, may move vertically through the profile, laterally on the soil surface and to a limited degree laterally through the profile. The degree, direction and rate of movement are dictated by explicit characteristics of the vegetation and soil and the rate of picloram applied. In general, when a low rate (0.5 lb/acre or less) is applied to rangeland, especially those with heavy-textured soils, downward movements is much less than where higher rates are applied to highly permeable, sandy soils. In fine sandy soils, detectable residues were rarely moved beyond the top foot of the profile following the application of only 0.25 lb/acre to rangeland in North and West Texas. Present data from various sources do not indicate extensive sorption of picloram by the soil colloid or rapid detoxification by microorganisms. Dilution in the soil may be one of the most important, practical means of dissipating picloram. Subsurface lateral movement is also dependent on direction and rate of soil water flow. Subsurface lateral movement, however, is apparently of lesser importance than vertical mobility in the soil profile. On slopes exceeding 3 to 4%, lateral subsurface movement may be more important than indicated by available data especially following high application rates and heavy rainfall.

Movement over the soil surface is governed primarily by intensity of rainfall, time-lapse from application to the first rain, rate of picloram applied, density and botanical composition of vegetation cover, texture of soil, and slope of the land. The longer the exposure on the soil surface before rainfall, the less picloram is available for movement. Rainfall of low intensity, especially before heavy rainfall, lessens the chance of surface runoff due to penetration of the soil by picloram. In North Texas, 17 parts per billion (ppb) of picloram occurred in surface runoff after application of 0.25 lb/acre to highly permeable, sparsely vegetated soils. Water samples were collected 10 days after treatment, immediately after applying 4 inches of simulated rainfall over a 9 hr period. Applications of 1 and 2 lb/acre of picloram to rangeland in South and Southwest Texas did not result in detectable residues in domestic water wells where samples were taken for up to 2 years following application.

Bovey and Scifres 1971 (con't.)

Once runoff water was moved to surface watering ponds under experimental conditions, dilution of picloram residues in the ponds prevented detection. Current methods allow detection of one part picloram per billion parts of water. Direct application of picloram, under experimental conditions, equivalent to 1 or 2 lb/acre showed that dilution was an important mode of picloram dissipation. Dissipation curves, concentration of picloram in pond water versus time, indicate loss to be concentration dependent. Initial loss rates are rapid, then concentrations "level off" at 1 or 2 ppb. However, these low concentrations may be detectable at up to a year after treatment of ponds. Research indicates vegetative growth of sensitive field crops would probably not be reduced using a single irrigation of water containing 1 to 4 ppb of picloram. Large volumes of water containing 4 ppb of picloram repeatedly applied to seedlings would probably reduce crop growth. However, residues of 10 ppb or more in irrigation water could severely affect the growth of some sensitive crop seedlings.

Recent research in dry areas of Texas indicate rapid initial loss of picloram from grasses. Loss rates of 2.5 to 3 %/day for 30 days were measured. There are indications, however, that grass roots may extract picloram from the soil profile and transport it to aerial portions of the plants. Such accumulations have not been observed in more humid areas of the state where rates of 4 to 8 times those used in drier areas were applied and the picloram was rapidly leached to the lower portions of the soil profile.

Picloram residues in the environment do not appear harmful to mammals, fish, birds or insects which inhabit the ecosystem. Mammals are tolerant to relatively high concentrations of the herbicide without displaying detrimental affects. Picloram passes rapidly, intact, through mammalian systems. Biological significance is related primarily to susceptible plant life, especially cultivated food and fiber crops in adjoining areas is of the greatest concern to rangeland managers when chlorophenoxy herbicides are applied because of possibilities of drift. Similar or more extensive crop injury could result from picloram if drift were allowed. However, for many weed species, picloram may be applied in the fall when susceptible crops are not grown. Pelleted and granular formulations of picloram would minimize the drift hazard.

Helling, C. S. 1971. Pesticide mobility in soils. I. Parameters of thin-layer chromatography. Soil Sci. Soc. Am., Proc. 35:732-748. (Research Soil Scientist, USDA-ARS, Beltsville, Md.; research conducted in Frederick Co., Md.).

Pesticide movement was studied using the recently developed soil thin-layer chromatographic (TLC) method. Thin layers of soil, the adsorbent phase, are developed with water using techniques analogous to conventional TLC.

Helling 1971 (con't.)

Mobility, expressed as R_F values for frontal movement, was insensitive to these parameters: removal of coarse or medium sand, movement distance, soil layer thickness, temperature, and sample size (0.3 to 50 μg). Water flux was modified by physical, soil amendment (inorganic and organic additives), and solvent amendment methods. Increased flux may slightly increase mobility of pesticides. The mobilities of 2,4-D and atrazine decreased markedly in >0.5M NaCl solution, whereas some movement of paraquat then occurred. Distance to the wetting front on soil TLC plates was linearly related to the square root of time.

Three methods of visualizing radioactive pesticide movement were compared: autoradiography, radiochromatogram scanning, and zonal extraction.

Horvath, R. S. 1971. Microbial cometabolism of 2,4,5-trichlorophenoxyacetic acid. Environ. Contam. Toxicol. Bull. 5:537-541. (Title unknown, Dep. Agronomy, Cornell Univ., N. York; research conducted at Cornell Univ.).

The results of this investigation are important from the points of view of microbial biochemistry, microbial ecology and environmental pollution. Prior to this work, no organism had been found which could effect a significant change of the 2,4,5-T molecule. The results presented in this paper demonstrate the microbial degradation of this herbicide. The degradation of both 2,3,6-trichlorobenzoate and 2,4,5-trichlorophenoxyacetate by microbial cometabolism indicates the environmental importance of cometabolism in the degradation of some supposedly recalcitrant molecules. The end product of 2,4,5-T degradation, 3,5-dichlorocatechol, has also been found to be a product of the microbial degradation of 2,3,6-TBS and 2,4-D. This catechol was shown to be completely metabolized by the *Arthrobacter* responsible for 2,4-D degradation. In addition, the author demonstrated the cometabolism of this compound by an *Achromobacter* sp. Thus, it would appear that both 2,3,6-TBA and 2,4,5-T can be completely degraded by a series of cometabolic reactions or by the action of two or more microbial species. In light of these findings, the concept of molecular recalcitrance should be reexamined. Inability of microorganisms to grow at the expense of an organic compound can no longer be interpreted to mean that the compound is recalcitrant, or the microorganisms fallible. It would appear that under the correct environmental conditions, most, if not all, organic compounds can be degraded either by complete mineralization of the molecule or by the phenomenon of cometabolism.

Scifres, C. J., R. R. Hahn, and M. G. Merkle. 1971. Dissipation of picloram from vegetation of semiarid rangelands. Weed Sci. 19: 329-332. (Asst. Prof. and Research Assoc., Dep. Range Science, and Prof., Dep. Crop and Soil Sci., Texas A&M Univ., College Station; research conducted at 3 locations in the Rolling Plains of Texas).

About 25 ppm of 4-amino-3,5,6-trichloropicolinic acid (picloram) usually were detected on grass, primarily buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.) and blue grama (*Bouteloua gracilis* Willd. *ex* HBK Lag *ex* Griffiths), immediately after application of 0.28 kg/ha picloram + 0.28 kg/ha (2,4,5-trichlorophenoxy)acetic acid (2,4,5-T) in northwest Texas. Less than 1 ppm of picloram usually was detected in grass tissue 30 to 60 days after treatment. At one location, detectable picloram increased in grass tissue from 32 to 60 days after application. Increases of picloram in aerial grass tissue were attributed to root uptake during a flush of vegetative growth. Picloram dissipation from grasses was not affected by irrigation to runoff at 10, 20, or 30 days after application. Detectable picloram was reduced by 93% in herbaceous, broadleaf species by 30 days after application. Treated sand shinnery oak (*Quercus havardii* Rydb.) leaves at the soil surface caused a slight increase of picloram in surface litter.

Bovey, R. W. and J. R. Baur. 1972. Persistence of 2,4,5-T in grasslands of Texas. Environ. Contam. Toxicol. Bull. 8:229-233. (Titles not reported, USDA-ARS, College Station, Texas; research was conducted throughout Texas).

The herbicide 2,4,5-T is relatively short lived in Texas grassland ecosystems and does not produce significant residues that persist from one year to the next at the rates and locations studied.

Horvath, R. S. 1972. Microbial co-metabolism and the degradation of organic compounds in nature. Bacteriol. Rev. 36:146-155. (Titles unknown, Dep. Biology, Bowling Green State Univ., Bowling Green, Ohio; literature review).

Stojanovic, B. J., M. V. Kennedy, and F. L. Shuman, Jr. 1972. Edaphic aspects of the disposal of unused pesticides, pesticide wastes, and pesticide containers. J. Environ. Quality 1(1):54-62. (Prof. of Soil Microbiology, Assoc. Prof. of Biochemistry and Assoc. Prof. of Agr. and Biol. Engineering, respectively, Miss. State Univ., State College, Miss.; research conducted in Miss.).

With a view toward the disposal of large quantities of pesticides in the soil, the biodegradation and the effects on the soil microflora of 20 single analytical grade and formulated pesticides and 7 mixtures of formulations were investigated in a calcareous West Point loam. The soil was amended with 11,227 kg/ha (5 tons/acre) of the respective active ingredient(s) and subsequently incubated for 56 days. The extent of biodegradation was estimated from the CO_2 evolved during the incubation and the effects on the microbial populations were determined from plate counts of the incubated samples. Four of the standards and eight of the formulations apparently were partly degraded. Single pesticides severely inhibited bacterial growth but affected streptomyces and fungi much less drastically. Mixtures of formulations seemed to be more biodegradable than the single pesticides provided that at least 1 or 2 pesticides in a mixture were relatively rapidly biodegraded. The mixtures severely reduced the numbers of bacteria but in general favored growth of streptomyces and fungi. Incineration of liquid formulations at 900 C produced little ash. The incineration of solids, however, yielded substantial amounts of incombustible residues. Analysis of the ash from the solids indicated in several cases the presence of toxic elements such as Br, As, Zn, etc.

Weber, J. B., S. B. Weed, and T. J. Sheets. 1972. Pesticides--how they move and react in the soil. Crops and Soils 25:14-17. (Weed and Soil Scientist, Soil Scientist, and Entomologist and weed scientist, N. Carolina State Univ.; location where research conducted unknown).

Altom, J. D. and J. F. Stritzke. 1973. Degradation of dicamba, picloram, and four phenoxy herbicides in soils. Weed Sci. 21:556-560. (Grad. Research Asst. and Asst. Prof., Dep. Agron., Oklahoma State Univ., Stillwater; research conducted near Stillwater and Lamar, Okla.).

The degradation rates of 2,4-D ((2,4-dichlorophenoxy)acetic acid), dichlorprop ((2-(2,4-dichlorophenoxy)propionic acid)), 2,4,5-T (2,4,5-trichlorophenoxy)acetic acid), silvex ((2,(2,4,5-trichlorophenoxy) propionic acid)), dicamba (3,6-dichloro-o-anisic acid), and picloram (4-amino-3,5,6-trichloropicolinic acid) were determined in three soils. Herbicide breakdown was proportional to herbicide concentration, so half life of the various herbicides was calculated from linear regression of the logarithm transformed residue data. The average half life for 2,4-D, dichlorprop, silvex, 2,4,5-T, dicamba and picloram were respectively, 4 days, 10 days, 17 days, 20 days, 25 days, and greater than 100 days. The rate of degradation of 2,4-D was the same in all three soils, but for the other herbicides it was consistently faster in soil removed from under grass vegetation than from under trees.

Kearney, P. C., E. A. Woolson, A. R. Isensee, and C. S. Helling. 1973. Tetrachlorodibenzodioxin in the environment: Sources, fate, and decontamination. NIEHS Conf. Chloronated Dibenzodioxins and Dibenzofurans. Mimeogr. material. 12p. (Titles unknown, USDA-ARS, Beltsville, Md.; review article).

A major research effort was initiated in the Agricultural Research Service, U.S. Department of Agriculture to investigate the inputs of and major biological processes affecting 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). A chemical survey of the major phenolic pesticides indicated the herbicide 2,4,5-T ((2,4,5-trichlorophenoxy) acetic acid) contained TCDD. Between 1960 and 1969, the total U.S. production of 2,4,5-T was 106.3 million lb. The level of input of TCDD on a yearly basis differed with the manufacturer, but ranged from nondetectable (<0.01 ppm) to 40 ppm. Environmental studies indicated that TCDD does not leach in soils, is not taken up into the economic portion of plants growing on contaminated soils, and is degraded to about 50% of the initial concentration after 1 year in soils and was not detected in soils which received 947 lb/acre of 2,4,5-T 2 to 5 years after application. TCDD is not formed by microbial or chemical condensation of 2,4,5-trichlorophenol in soil.

Kearney et al. 1973 (con't.)

Several options are available for the decontamination of surplus stocks of 2,4,5-T containing TCDD. These include incineration, soil biodegradation, chemical conversion to carbon tetrachloride, and purification for use as a herbicide. The feasibility and environmental implications of each are currently under investigation.

Lutz, J. F., G. E. Byers, and T. J. Sheets. 1973. The persistence and movement of picloram + 2,4,5-T in soils. J. Environ. Quality 2:485-488. (Prof., Grad. Research Asst., and Prof.-in-charge, Pesticide Research Lab., Dep. Agr. and Marketing, Province of Nova Scotia, Truro, Nova Scotia, Canada; research conducted in Haywood, Co., N. Car.).

The movement and persistence of picloram (4-amino-3,5,6-trichloro-picolinic acid) and 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) were studied on a western North Carolina watershed on which extensive agronomic, hydrologic, and climatic data had been accumulated over a period of 18 years. Picloram was more persistent than 2,4,5-T; approximately 60% of the picloram and 90% of the 2,4,5-T disappeared in 15 days. There was some penetration into the soil, but a very high percentage of the total amount present at the different sampling periods was in the 0 to 7.5 cm layer. Doubling the application rate (4.48 vs. 2.24 kg/ha) resulted in a two-fold increase in the amount of herbicide recovered at each sampling period. Very little downslope movement of either herbicide occurred even though the average slope on the plots was approximately 27%. Practically no herbicide was found more than 0.3 m, and none beyond 1.2 m, downslope. More picloram than 2,4,5-T moved.

O'Connor, G. A. and P. J. Wierenga. 1973. The persistence of 2,4,5-T in greenhouse lysimeter studies. Asst. Prof. and Assoc. Prof., Dep. Agron., New Mexico State Univ., Las Cruces, N. Mex.; research conducted in N. Mexico).

The persistence of 2,4,5-T was evaluated in an agricultural soil under favorable microbial conditions in lysimeters. Degradation was most rapid in a soil previously treated with the herbicide if extended periods of time did not separate herbicide additions. The degradation of 2,4,5-T was more rapid when the herbicide was applied at 40 ppm than

O'Connor and Wierenga 1973 (con't.)

when it was applied at 80 ppm. The time required for biological detoxification varied from 48 to 85 days depending upon pretreatment and concentration of the applied herbicide.

Baur, J. R., R. W. Bovey and H. G. McCall. 1974. Thermal and ultraviolet loss of herbicides. Pestic. Abstr. 8(4):217. 74-1031. (Arch. Environ. Contam. Toxicol. 1:289-302, 1973). (Titles unknown, USDA-ARS, College Station, Texas; location where research conducted unknown).

Exposure of free acids of picloram and 2,4,5-T to temperatures of 30° and 60° for 7 days resulted in 24% and 55% loss, respectively, at the higher temperature and no change at the lower temperature. Under the same conditions the free acid of dicamba was reduced 60% at 30° and 92% at 60°. Salts of picloram and 2,4,5-T were slightly more susceptible to thermal loss than the free acids, while the potassium salt of dicamba was more resistant than the free acid. A loss greater than that caused by temperature alone was observed on long-wave UV irradiation of free-acid and potassium salt of picloram and the potassium salt of 2,4,5-T. Ultraviolet degradation of free-acid picloram was shown to occur by a direct interaction of one photon of UV light with each molecule. Dicamba appeared to be less susceptible to UV degradation.

O'Connor, G. A. and J. U. Anderson. 1974. Soil factors affecting the adsorption of 2,4,5-T. Soil Sci. Soc. Am., Proc. 38:433-436. (Asst. Prof. and Prof., Dep. Agronomy, N. Mexico State Univ., Las Cruces; research conducted in N. Mexico).

Factors expected to affect the adsorption of 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) on four soils of the western USA were studied. The effects were examined by equilibrating solutions of 2,4,5-T with soils in their natural conditions, after Ca saturation, and with samples of the same soils treated to remove soil constituents expected to affect adsorption. Organic matter was an important contributor to 2,4,5-T adsorption, and in some soils, was the only absorbent of significance. Oxides of Fe and Al did not contribute much to adsorption in the soils studied although the pH of soils studied was only slightly acid to alkaline. Allophane was apparently an effective adsorbent when the Si/Al ratio of the allophane was high.

Bartleson, F. D., Jr., D. D. Harrison, and J. D. Morgan. 1975. Wildlife (mammals) observations on TA C-52A, p. 29. In, Field studies of wildlife exposed to TCDD contaminated soils. Final report ending February, 1975. Air Force Armament Laboratory. (Eglin Air Force Base, Florida). (Lt. Col., unknown title and 1 Lt. (USAF), respectively; research conducted at Eglin Air Force Base).

A study was made of the birds, other wildlife, and soils in two area of the Eglin Air Force Base Reservation, Florida, which previously had been exposed to massive quantities of military herbicides containing the highly toxic chemical 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). The studies were conducted on a 3 mi^2 test site (Test Area C-52A) where aerial dissemination equipment was tested and around a hardstand where the spray-aircraft were loaded. TCDD was found to be persistent and widespread in these areas. No positive deleterious effects from the TCDD were found. Evidence was found, however to suggest that selected species of wildlife, in restricted habitats, might have been affected. TCDD had entered certain food chains, and bioaccumulation was demonstrated. Transient wildlife and certain herbivorous animals appeared to suffer no ill effects. Recommendations were made for a method to accelerate degradation of TCDD in terrestrial environments and for specific follow-up studies on TCDD wildlife effects.

Byast, T. H. and R. J. Hance. 1975. Degradation of 2,4,5-T by South Vietnamese soils incubated in the laboratory. Environ. Contam. Toxicol. Bull. 14:71-76. (Titles unknown, Agr. Res. Council Weed Res. Org., Begbroke Hill, Oxford, Great Britain; research conducted on 4 soils from South Vietnam).

During the preliminary investigations of the National Academy of Sciences Committee on the Effects of Herbicides in Vietnam, soil and mud samples were taken from areas some of which were though to have received applications of Agent Orange (a 50:50 mixture of the n-butyl esters of 2,4-D and 2,4,5-T) during military defoliation operations. These samples were sent to this laboratory for the determination of possible residues. However, the quantities were greater than necessary for this purpose, so the opportunity was taken to use the surplus to obtain an indication of the capacity of these soils to degrade 2,4,5-T.

Konnai, M., Y. Takeuchi, and T. Takematsu. 1975. Fundamental studies on residues and movement of forestry herbicides in soil. Pestic. Abstr. 8(7):450-451. 75-1581. (Titles unknown, Utsunomiya Univ., Japan; research conducted in Japan).

Experimental results (covering the period 1969 to 1972) regarding the behavior in the soil of some major herbicides used in forested areas are presented. Movement was greater with inorganic compounds whose basic structures are charged negatively (ClO_3-, NH_2SO_3-) while the degree of translocation in the soil varied according to factors such as soil type, humus, amount and intensity of rainfall, and inclination of land. Chlorate, sulfate, and fatty acid type herbicides showed greater movement than phenoxy and benzoic acid type herbicides. Esterified compounds revealed much less movement and were firmly adsorbed on the soil surface. Herbicides of high water solubility with negative charges closely correlated with the movement of soil water. Six compounds tested with regard to residues were inactivated completely after 4 to 14 weeks when applied at standard dosage. Inactivation tended to be rapid with DPA (2,4-dichloropropionic acid) and slow with TFP (2,2,3,3-tetrafluoropropionic acid) and AMS (ammonia sulfamate). The term of residue persistence was prolonged as the dosages increased, especially with TFP, TBA (2,3,6-trichlorobenzoic acid), and 2,4,5-T (2,4,5-trichlorophenoxy acetic acid). The length of residue persistence tended to become shorter as microorganisms proliferated. Experiments were carried out by means of bioassays using plant seeds which are sensitive to weed-killers and were conducted in the laboratory and in fields and forest lands.

Newton, M. and L. A. Norris. 1975. A discussion on herbicides. J. Forest. 73:410-412. (Assoc. Prof., Oregon State Univ. and Supervisory Research Chemist, USDA-FS, Corvallis, Oregon; journal interview).

Intensive management of the forest is necessary to meet society's demand for the many products of the forest. The herbicide 2,4,5-T was introduced into general use in agriculture, forestry, and roadside and rights-of-way uses in 1947. 2,4,5-T plays a critical role in the management of northwest forest lands. It is used in the reforestation of sites which are capable of growing a conifer forest but which have been dominated by brush species for a long period of time. It is also used to insure the survival and increase the growth of conifers which are suppressed by competing brush species.

Newton and Norris 1975 (con't.)

Hand slashing, machine clearing, and fire are not satisfactory brush control techniques because of high cost, low effectiveness, and unacceptable environmental impacts in some cases. A wide variety of herbicides have been tested on northwest brush species, but they cannot replace 2,4,5-T for the control of many species.

No human health problems or effects on other animals of any sort had been associated with these widespread uses of 2,4,5-T over a 22-year period; however, in 1969, a research laboratory which was developing a very sensitive test method for cancer and birth defects found a significant induction of fetal deformities by 2,4,5-T under these special test methods. This was surprising to many research workers, and examination of the 2,4,5-T used in the tests revealed that the batch in use had an impurity called dioxin or TCDD present at the unusually high level of 27 ppm. It was determined over the course of many more studies that it was this impurity which caused these deformities, not the 2,4,5-T. TCDD is formed as a by-product of one of the steps in the manufacture of 2,4,5-T. The amount of TCDD is greatly influenced by the conditions in the process, particularly high temperatures and alkaline conditions. TCDD is now legally restricted to less than 0.1 ppm of the product 2,4,5-T.

Historically, the presence of dioxins in phenoxy herbicides has been known since the late 1940's when accidental release of the chemical impurity in a 2,4,5-T plant caused chloracne in several workers and studies showed the dioxins to be the cause. However, it was not until as recently as 1970-1971 that the extreme toxicity of TCDD became known. Before that time, concern about dioxins was not sufficient to encourage good quality control during production of 2,4,5-T and little documented information is available on the levels of dioxins (TCDD) in earlier lots of 2,4,5-T.

It has been possible to demonstrate that very high doses of pure 2,4,5-T are capable of producing birth defects. The effective doses are so high relative to application for plant control that there is little dispute as to the safety of pure 2,4,5-T. Pure TCDD, in contrast, is the most toxic synthetic chemical known. In spite of the great toxicity, however, the hazard of using 2,4,5-T containing less than 0.1 ppm TCDD is exceedingly limited.

The probability that animals and people may be exposed to biologically significant quantities of 2,4,5-T or TCDD is determined by the movement, persistence and fate of these chemicals in the environment. 2,4,5-T has been extensively studied. It does not enter forest stream surfaces. The concentration of 2,4,5-T declines rapidly in vegetation (80% to 99% decrease in 30 days) and in the forest floor and soil (90% in 6 months). 2,4,5-T which may be consumed along with recently sprayed vegetation does not accumulate in the body and 80% or more is typically excreted in 3 days.

Newton and Norris 1975 (con't.)

TCDD has not been as extensively studied because it only came to the attention of the scientific community in the last 5 years. However, several important properties of TCDD have been determined. TCDD does not leach in soil and is subject to degradation with about half the TCDD disappearing in 1 year. It is calculated that a 1 lb/acre application of 2,4,5-T containing 0.1 ppm TCDD applied directly to the soil could result in a maximum of 0.1 parts per trillion TCDD in soil. TCDD does not appear in the seeds of plants grown in soil containing even large amounts of TCDD. It has a very high affinity for surfaces, and it should be expected to bind to the waxy cuticle of leaves so tightly that removal by contact is doubtful. The compound is almost completely insoluble in water, and even when dissolved in vegetable oil, is not easily absorbed from the digestive tract.

Animals receiving TCDD excrete about 1/3 immediately and 1/2 of the balance is excreted in 17 days. The highest concentration of TCDD appears in the liver and small quantities in other body tissues. The remainder continued to decline at this rate with time.

Data from experimental animals indicate that immediately after spraying at an accepted treatment rate, a 100 lb human could absorb all the TCDD on 1 acre of forest and suffer no toxic effect. This is a conservative estimate. TCDD is so tightly bound by vegetation and soil that the probability of significant intake by humans is remote.

Most parties to the question of whether 2,4,5-T (with the impurity dioxin at a level less than 0.1 parts per million) should be sprayed in our forests agree on the essential facts about toxicity and behavior of these chemicals. The difference in the conclusions reached is a result of concern about the possibility of even one birth defect resulting from the use of 2,4,5-T containing any dioxin. This concern leads to the question of whether even one molecule of a toxic chemical if present in the right human cell at the right time, could react with the proper molecule in the cell and result in a birth defect. While this may be "philosophically possible," it must also be asked it it is "practically possible" or probable. Because of the existence of cellular repair mechanisms and the low probability of a single toxic molecule finding and reacting with one correct target molecule out of 100 trillion other molecules in a particular cell at the right time, most toxicologists believe that the single molecule concept of toxicity should not be termed as "possible" but as "practically impossible." That is, most toxicologists believe that there is a threshold of response below which no harmful effects are produced.

We believe the registered uses of 2,4,5-T in the forest do not constitute an unacceptable hazard to humans, animals, or the general quality of the environment.

Norris, L. A., M. L. Montgomery, and E. R. Johnson. 1977. The persistence of 2,4,5-T in a Pacific Northwest forest. Weed Sci. 25:417-422. (Superv. Res. Chem., USDA-FS, and Senior Instr. and Asst., Dep. Agr. Chem., Oregon State Univ., Corvallis; research conducted near Vernonia, Oregon).

The concentrations of 2,4,5-T (2,4,5-trichlorophenoxy)acetic acid) in four species of vegetation varied from 11 to 115 ppmw immediately after application at 2.24 kg/ha but were less than 0.5 ppmw after 1 year. The 2,4,5-T level in forest floor declined 90% during the first 6 months after application and less than 0.02 kg/ha remained after 1 year. There was little leaching of 2,4,5-T from the forest floor into soil and no residues were found deeper than 15 cm. Maximum soil residues did not exceed 0.1 ppmw. Residue levels and dissipation rates of 2,4,5-T were similar after one and two successive annual applications.

Plumb, T. R., L. A. Norris, and M. L. Montgomery. 1977. Persistence of 2,4-D and 2,4,5-T in chaparral soil and vegetation. Environ. Contam. Toxicol., Bull. 17:1-8. (Titles unknown, USDA-FS, Riverside, Calif. and Corvallis, Ore.; research conducted east of San Diego, Calif.).

Our results suggest that concern about the potential hazard of 2,4-D and 2,4,5-T residues in arid southern California soils seems unwarranted. Even under conditions which are considered poor for rapid herbicide degradation--namely, low rainfall and moderately coarse soils with relatively low organic matter content--residues of 2,4-D and 2,4,5-T disappeared rapidly. Normally there would be little opportunity for chemical leaching after a spring herbicide application in southern California since little rainfall is expected until the fall. In fact, only a slight amount of leaching of phenoxy herbicides is expected under water climatic conditions.

The major potential hazard to water quality is through surface water contamination; even then, peak concentrations are usually low and short duration. In an average rainfall year, most streams are dry in California chaparral areas during late spring and summer; consequently, direct water contamination should be minimal. Where streams or standing water are present, buffer zones can be used to minimize direct application to surface waters.

We conclude that the use of 2,4-D and 2,4,5-T for management of fuelbreak vegetation does not present a significant hazard to the quality of the environment nor to its inhabitants.

Scifres, C. J., H. G. McCall, R. Maxey, and H. Tai. 1977. Residual properties of 2,4,5-T and picloram in sandy rangeland soils. J. Environ. Quality 6:36-41. (Prof. and Research Assoc., Texas Agr. Exp. Sta., College Station, Texas, Chemist and Director, Pestic. Monit. Lab., EPA, Bay St. Louis, Miss.; research conducted near Bastrop and Calwell, Tex.).

Two watersheds were treated with one application of 2,4,5-T + picloram (1:1) at 1.12 kg/ha while one other watershed was treated for 2 consecutive years at the same herbicide rates. Residues of 2,4,5-T were reduced to trace levels (<10 parts per billion (ppb)) in soils 7 days after application at one location, after 28 days at the second, and after 56 days at the third. Residues of 2,4,5-T were not detected below 15 cm and usually remained in the surface 2.5 cm of soil. Picloram was reduced to trace levels within 56 to 112 days after application, was not detected deeper than 60 cm, and was usually restricted to the surface 15 cm of soil. There was no evidence of subsurface lateral movement of either herbicide. Surface runoff water contained trace amounts of residue following storms for about 30 days after application. There was not evidence of residue carry over into the second year after treatment in water, soils, or vegetation. Monitoring of cumulative residues in water, soils, and vegetation showed that about 75% of the picloram was dissipated from the ecosystem within 28 days after application and over 90% was lost after 112 days.

Brady, H. A. 1973. Persistence of foliar-applied 2,4,5-T in woody plants. Southern Weed Sci. Soc., Proc. 26:282 (Abstr.). (Research Soil Scientist, USDA-FS, Pineville, La.; research conducted in the southern forest of U.S.).

Radioactive 2,4,5-T persisted 3 to 7 times as long in treated woody plants as in forest soils. The half-life of the herbicide was 5.5 weeks in loblolly pine (*Pinus taeda* L.), 5.8 weeks in post oak (*Quercus stellata* Wangenh.), 6.7 weeks in sweetgum (*Liquidambar styraciflua* L.), and 12.4 weeks in red maple (*Acer rubrum* L.). It took slightly less than 2 weeks for half the applied dose to disappear from treated soil in the same study.

In another study, sweetgum, red maple, and loblolly pine absorbed a greater proportion of a lethal dose of 2,4,5-T than of a sublethal one. Blackjack oak (*Q. marilandica* Muenchh.) did not. From 97 to 99% of the lethal dose remained in treated leaves, however, while significantly more of the nonlethal dose was translocated to the roots of all species.

Brady 1973 (con't.)

All four species decarboxylated 2,4,5-T, releasing $^{14}CO_2$, with no significant differences between species or doses. They also released 2,4,5-T into the soil from the roots. Sweetgum, however, released more from both the high and low dosages than the other species.

Hamaker, J. W., C. A. I. Goring and C. R. Youngson. 1966 . Sorption and leaching of 4-amino-3,5,6-trichloropicolinic acid in soils. In, R. I. Gould (ed.), Organic Pesticides in the Environment. Adv. Chem. Series 60:23-37. (Title unknown, Bioproducts Research Lab., The Dow Chemical Co., Walnut Creek, Calif.; location where research conducted unknown).

The greatest sorption of 4-amino-3,5,6-trichloropicolinic acid, 2,4-D, and 2,4,5-T was observed for soils containing a high percentage of organic matter and for red and acidic soils. Leaching from columns of these soils confirmed this order of sorption. Maximum sorption was attained rapidly by red soils but slowly by highly organic soils. Exhaustive washing with hot water or treatment with sodium hydroxide quantitatively removed sorbed 4-amino-3,5,6-trichloropicolinic acid from all but muck soils. The data suggest that sorption of 4-amino-3,5,6-trichloropicolinic acid is primarily caused by organic matter and hydrated metal oxides, with clays probably playing a minor role. Sorption of unionized 4-amino-3,5,6-trichloropicolinic acid and its anion was involved.

Morton, H. L., L. J. Lane, D. E. Wallace, R. D. Martin, and R. E. Wilson. undated. Movement of water soluble herbicides on semiarid rangelands. Mimeigr. material. (Titles unknown, USDA-ARS, Tucson, Ariz.; research conducted on Santa Rita Exp. Range, Ariz.).

The Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500) require that we restore and maintain our water quality. For agricultural activities on rangelands this means that we must understand the hydrologic systems present under any given set of conditions, and be able to predict the effects of various land uses including livestock grazing and range improvement practices.

III. Pollutant and Toxic Hazards
B. Mobility and Degradation Rate

SUMMARY AND CONCLUSIONS

Mobility and degradation rate of herbicides in an ecosystem are dependent on several variables, including type of herbicide, soil texture, soil organic matter content, photodecomposition, precipitation, etc. However, it appears that most herbicides used in mesquite control degrade relatively rapidly.

Herbicidal activity of 2,4,5-T has been retained in soil more than 80 days after application (DeRose, 1946). Residual of 2,4,5-T seems to be between 48 and 270 days (DeRose and Alexander, 1947; Audus, 1951; Newman et al., 1952; Bovey and Baur, 1972; Altom and Stritzke, 1973; O'Connor and Wierenga, 1973; Konnai et al., 1975). DeRose and Newman (1947), Howath (1971) found that microbial activity was important in the detoxification, since 2,4,5-T was much more persistent in autoclaved soils. Degradation of 2,4,5-T occurs in three phases: (1) immediate initial adsorption onto soil colloids, (2) a lag phase in which there is very little disappearance of the herbicide, and (3) a final phase of rapid complete detoxification (Audus, 1951). Initially, 90% of 2,4,5-T disappears in 15 days in some soils (Lutz et al., 1973), while in others 2,4,5-T has a half-life of 20 days (Altom and Stritzke, 1973). Norris et al. (1977) reported that 90% of 2,4,5-T applied to a forest community declined from the forest floor during the first 6 months after application and that no residues were ever found deeper than 15 cm.

Herbicide residues in woody plant material have only occasionally been examined. Brady (1973) found that 2,4,5-T persisted 3 to 7 times longer in woody plants than in forest soils. However, 90 to 99% of the herbicide recovered in woody tissues of live oak had disappeared 6 months after the trees were treated (Baur et al., 1969).

Degradation rates of picloram are generally slower than those of 2,4,5-T. Detectable quantities of picloram remained in soil incubated for 1 year at 4, 20, and 38 C at two moisture levels (Merkle et al., 1967). However, if picloram remains at the ground surface exposed to sunlight, it will photodecompose relatively rapidly (Baur et al., 1974). The half-life for picloram is more than 100 days (Altom and Stritzke, 1973). Approximately 60% of the picloram applied disappeared from soil within 15 days (Lutz et al., 1973).

Picloram disappears more rapidly from vegetation than from soils. Loss rates of 2.5 to 3.0%/day have been measured for 30 days (Bovey and Scifres, 1971). Less than 1 ppm of picloram was detected in grass tissue 30 to 60 days after application (Scifres et al., 1971).

The rate of degradation of dicamba is intermediate to 2,4,5-T and picloram, however, it is more similar to 2,4,5-T. The half-life for dicamba is about 25 days (Altom and Stritzke, 1973). Dicamba is relatively susceptible to thermal degradation but resistent to photodecomposition (Baur et al., 1974).

Most research has been conducted on 2,4,5-T, but it appears that 2,4,5-T has the least residual and most rapid degradation of the herbicides used in mesquite control.

IV. Alternative Methods of Control
A. Effectiveness

Humphrey, R. R. 1949. Fire as a means of controlling velvet mesquite, burroweed, and cholla on southern Arizona ranges. J. Range Manage. 2:175-182. (Title unknown, Univ. Ariz.; research conducted in southern Ariz.).

Many desert shrubs growing in southern Arizona can be rather effectively controlled by broadcast burning. Control is more nearly complete on burroweed than on the other species observed, although even on velvet mesquite trees 5 to 10 ft in height, a rather effective kill has been observed. These general conclusions were reached as early as 1910 by workers of the Bureau of Plant Industry and the University of Arizona. The conclusions reached by those early workers have been corroborated by an analysis of the effect of two burns that occurred in 1933.

In the case of burroweed, there is no doubt that burning during the dry season just preceding the summer rains may be almost 100% effective. The effect of running ground fires on other common shrubby species, however, needs additional thorough study. Control of shrubs by fires is often difficult because the ground cover is too sparse to carry a fire. This difficulty can be overcome in part by excluding livestock from the area to be burned for a winter or a winter and summer season preceding burning.

When chopped or otherwise cut down at or above ground level velvet mesquite almost invariably stump sprouts and eventually develops another tree. Why many individuals of the species behave differently after burning is not known. An explanation is suggested here that may account for this seeming inconsistency.

Ground fires in velvet mesquite country are rarely hot enough to burn into the xylem of such large shrubs or trees as mesquite. They may, however, kill the cambium and all tissues outside the cambium. In effect, therefore, these trees have been girdled, thus depriving the roots of carbohydrates though not preventing translocation of minerals, carbohydrates and water from the roots into the stems. Girdling is known to be an effective method of killing many hardwood trees that normally stump sprout vigorously if cut down. The lethal effect of burning on velvet mesquite may be due to the same plysiological principle.

Although the total number of grass plants, regardless of species, was greater after burning on both areas studied, the evidence as to the effect of fire on the various grasses is rather inconclusive. Both burned areas were small and as a result pressure from rabbits and domestic livestock was considerably heavier than on the adjacent range.

Humphrey 1949 (con't.)

No counts of either of these animals were made. Both were observed, however, to show a marked preference for the relatively open, burned areas. As a consequence, the burns were subjected to rather heavy overgrazing.

Although the Beach Ranch and Sierrita Mountain areas were studied primarily to obtain information on burroweed and forage species, the observations made on trees and other shrubs are also of value. While investigations to date are indicative rather than conclusive, they do suggest a relatively cheap and effective method of keeping these plants in check where ground is adequate to carry fire.

Blydenstein, J. 1957. The survival of velvet mesquite (*Prosopis juliflora* var. *velutina*) after fire. J. Range Manage. 10:221-223. (C. L. Pack Forestry Found. Fellow, Dep. Agronomy and Range Manage., Univ. Ariz., Tucson; research conducted in Pinal Co., Ariz.).

The damage to velvet mesquite in southern Arizona by fires during different seasons was studied to appraise the theory that natural wildfires were formerly an important factor in preventing the spread of mesquite over the desert grassland, and to evaluate the use of controlled burning as a tool in the eradication of mesquite today.

The results from burns during both the dormant winter season and the active growing and flowering season indicate that single fires do not cause high mortality rates in mesquite, but many trees survive through basal sprouting only. A high degree of correlation was found to exist between size of tree and amount of damage, the smaller size-classes receiving the heaviest damage. Mortality was restricted to trees under 1 inch in diameter.

Heavy sprouting after total topkill reduces the stem diameter of many of the trees, suggesting that recurrent fires might cause higher mortality rates. As a tool in eradicating established mesquite stands, fire appears uneconomical due to the need for recurrent burns and adequate fuel. In the control of young invading mesquite on grasslands the use of fire should be investigated further.

Anon. 1958. It may pay to grub mesquite. Agr. Res. 7(6):12-13. (Credential unknown; research conducted on the Jornada Exp. Range, N. Mex.).

Anon. 1958 (con't.)

Mesquite grubbing--digging out the weeds with a grubbing hoe--may be an economical way to head off further losses of valuable grasslands in our Southwestern States.

A large-scale mesquite control project early this year on USDA's Jornada Experimental Range in southern New Mexico showed just how practical mesquite grubbing can be. Total labor cost in grubbing 4,265 acres of mesquite at 44 cents/acre was $1,876. A total of 2,531 manhours of labor was required, plus 84 hr of supervision.

Herbel, C., F. Ares, and J. Bridges. 1958. Hand-grubbing mesquite in the semidesert grassland. J. Range Manage. 11:267-270. (Research Agronomist, Range Conserv., USDA-ARS, and Rancher, Las Cruces, N. Mexico; research conducted on the Jornada Exp. Range, N. Mex.).

Hand-grubbing mesquite on 4,265 acres of typical semidesert grassland is reported. A method of laying out the grubbing area and a method of checking are explained in detail. An average of 0.592 man hr/acre was required for grubbing and flagging; an average of 0.043 man hr/acre for the combination supervisor and clean-up man. It is proposed that more attention be given to this economical method of controlling light stands of small mesquite plants to avoid further loss of valuable grassland.

Cable, D. R. 1961. Small velvet mesquite seedlings survive burning. J. Range Manage. 14:160-161. (Range Cons., USDA-FS; Tucson, Ariz.; research conducted in southern Arizona).

Planned burning to reduce the number of shrubs and increase grass production has been used successfully in various parts of the western range area and with various shrub species. Fire may completely kill essentially all plants of nonsprouting shrub species. With sprouting species fire may kill some plants completely but only top-kill many others, which then sprout from the stem base or from the roots.

Such use of fire to control woody plants in the Southwest is largely in the experimental stage. The possibility of controlling invasion stands of velvet mesquite, a vigorous sprouter, by burning has been the subject of sporadic research in the Southwest. All trees with less than 2 inches basal diameter were affected by the burning, but 60% of them sprouted.

Cable 1961 (con't.)

A study was made on the Santa Rita Experimental Range near Tucson, Arizona, beginning in 1955, to learn more about the susceptibility of very young mesquite to fire. In this study young mesquite plants were at 2 ages: in March when 8 months old, and in June when 12 months old. The mesquite plants were transplanted into the grass stand as 3- to 4-week old seedlings. The burning treatments were applied by broadcast burning the good stand of annual and perennial grasses. The fuel provided by these grasses was sufficient to produce a clean burn.

Of the 34 live plants burned at 8 months of age, 23 were completely killed. The other 11 were top-killed and sprouted later from the base. Of 26 live plants burned at 12 months of age, 17 were completely killed; the other 9 were top-killed only and sprouted later. In both cases, the plants that were only top-killed were well distributed over the burned area.

Thus, burning killed about two-thirds of the mesquite plants, which were 4 to 6 inches tall and up to 1 year old. The other third were top-killed, but sprouted from the base. This ability of very young and very small velvet mesquite to sprout from the base when top-killed makes eradication by burning difficult if not impossible, although repeated fires might preserve a shrub-free appearance by repeatedly top-killing the mesquite plants.

Anon. 1965. Controlling honey mesquite. Agr. Res. 14(4):3-4. (Credentials unknown; research conducted on the Jornada Exp. Range, N. Mex.).

Brock, J. H., E. D. Robison, C. E. Fisher, B. T. Cross, and C. H. Meadors. 1970. Reestablishment of grasses following mechanical removal of brush. PR-2810, p. 38-46. In, Brush Research in Texas. Texas Agr. Exp. Sta., Texas A&M Univ., College Station, Texas. Consolidated Prog. Rep. 2801-2828. (Research Assoc., Research Assoc., Prof.-in-charge, Tech., and Research Assoc., Texas Agr. Exp. Sta.; research conducted throughout Rolling Plains of Texas).

Available information does not justify a final conclusion as to the success or failure of the various reseeding treatments. The data do, however, give some indications for establishment of various introduced and native species. Determination of the degree of success of the reseeding treatments should be made after a minimum of 2 years, at which

Brock et al. 1970 (con't.)

time establishment and survival of the species would be more meaningful in planning rangeland renovation programs.

The most successful grass stands were in those treatments in which use of a drill was the seeding method. Broadcast methods, both from an exhaust broadcast system and an aerial broadcast, resulted in stands that were less successful.

Discing plus roller chopping proved to be the best seedbed preparation on the Tongue River Ranch. The single operation of roller chopping, when compared with discing, resulted in better grass stands with fewer annual weeds. Aerial seeding a grass mixture onto root plowed and chained rangeland followed by roller chopping resulted in the most successful grass stands on the Waggoner Ranch plots.

Economically, from the standpoint of cost alone, perhaps the best method of reestablishing grasses on mechanically cleared rangeland was aerial seeding followed by a roller chopping operation. This treatment required less operational time since more acres were covered in less time than when a drill was used as the seeding method.

Carpenter, T. G. 1970. Brush shredding, p. 20. In, Noxious Brush and Weed Control Research Highlights. ICASALS Special Report No. 40. Texas Tech Univ., Lubbock. (Research Assoc., Dep. Agr. Engineering, Texas Tech Univ.; research conducted near Post, Texas).

Shredding has not been a very popular method of brush control. However, it could be a rather low-cost operation which should be investigated from the viewpoint of economics and effectiveness. Aside from economics, an effective shredding operation results in rapid destruction and decay of the brush residue, leaving the land clean and clear of obstructions. An initial shredding operation would clear the way for future maintenance and control operations.

Factors which appear to have discouraged shredding are:

1. Lack of usuable wheel-type tractors with tires which are acceptable.

2. Initial control methods, such as spraying, root plowing and chaining, leave large amounts of residue which interferes with shredding. Likewise, root plowing and grubbing leave the land rough and difficult to traverse for shredding.

3. Shredding often seems to produce a pruning effect which inhibits regrowth at a faster rate than growth prior to shredding.

Carpenter 1970 (con't.)

Better tires and changes in control methods may alleviate these problems.

One approach, which will be investigated in our research, will be the use of a large, heavy duty flail-type shredder which has been especially constructed for handling the larger brush found on most ranches. The basic shredder unit was constructed by a private concern for brush control work on the Moss Ranch near Afton, Texas. After a successful initial shredding operation, the ranch has been using a small shredder for maintenance and regrowth control. The larger shredder was recently donated to the Texas Tech Foundation for brush research. This shredder is now being reworked and equipped with a self-contained power unit. This unit will be utilized in shredding tests next spring.

Churchill, F. M. and J. L. Schuster. 1971. A new brush grubber for the Southwest. J. Soil Water Conserv. 26:200. (Prof., Dep. Agriculture, Abilene Christian Univ., Abilene, Texas, and Prof., Dep. Range and Wildlife Manage., Texas Tech Univ., Lubbock; research conducted in Nolan Co., Texas).

Tests began a year ago in Nolan County, Texas, with a new traxcavator grubber designed to control small brush species such as yucca (*Yucca* spp.) and lotebush (*Condalia* spp.). The basic unit is a Traxcavator 955H front-end loader built by Caterpillar. The bucket was removed and replaced by a cutting blade designed to fit the loader's arms.

The machine is able to tilt the blade just as the original unit was able to tilt the bucket. The blade enters the soil at a downward angle, is leveled off after severing the plant roots, and then is positioned at an upward angle to complete root removal. This action exposes most of the root system for dessication.

The grubber is capable of deep soil penetration (up to 28 inches) because the blade design minimizes power requirements. Its smooth tracks do not tear up the sod as much as cleated tracks do, and it is more maneuverable and can operate over rougher ground than rubber-tired excavators and front-end loaders. The blade action leaves shallow pits which are highly desirable for grass seeding.

After 6 months of testing the grubber, several advantages over a crawler-type tractor with a front-end grubber mounted on a dozer blade were noted. The operator's visibility of plants to be grubbed is greater with the traxcavator grubber. This increases the percentage of plants killed. Improved visibility also makes the traxcavator grubber more efficient. The operator usually needs to make only one grubbing pass with the traxcavator, whereas two or more attempts often are necessary with the dozer blade-type grubber before brush is uprooted.

Churchill and Schuster 1971 (con't.)

An extra set of cylinders on the front arms of the traxcavator allows excellent control of the blade's angle of penetration into the soil. Because the blade can be straightened out while beneath the soil, the shearing action reduces the amount of power needed. The new design also provides better blade-cleaning action and less accumulation of debris.

Once sheared, plant roots are exposed at the top of the soil where they become much more vulnerable to the effects of extremely hot or cold weather. Little soil is left on the root system.

The powershift transmission shifts automatically, enabling the operator to continue operation without stopping. This reduces operation time, thereby increasing production while decreasing cost.

Ueckert, D. N., K. E. Polk, and C. R. Ward. 1971. Mesquite twig girdler: a possible means of mesquite control. J. Range Manage. 24:116-118. (Asst. Prof., Grad. Research Asst., and Asst. Prof., Entomology Section, Texas Tech Univ.; research conducted in the Rolling Plains and the Trans-Pecos region of Texas).

The mesquite twig girdler (*Oncideres rhodosticta* Bates) was found to inflict considerable damage to mesquite in Texas and may prove to be a valuable biological control agent for this noxious species. Preliminary observations in infested areas indicated that about 90% of the mesquite trees had been attacked by the girdler and that about 40% of all branches from 0.5 to 2.0 cm in diameter had been girdled.

Wright, H. A. 1972. Shrub response to fire, p. 204-217. In, C. M. McKell, J. P. Blaisdell, and J. R. Goodin (ed.), Wildland Shrubs--Their Biology and Utilization. U.S. Dep. Agr., Forest Serv. General Tech. Rep. INT-1. Ogden, Utah. (Assoc. Prof., Range and Wildlife Manage., Texas Tech Univ., Lubbock; where research conducted unknown).

In general, fires suppress shrubs in grasslands, promote them in forests, and stimulate them in chaparral communities. However, we should always evaluate the effect of the fire, season of burn, health of herbaceous plants (particularly grasses in grasslands), and the frequency of droughts. All of these factors can, and usually do, affect

Wright 1972 (con't.)

the response of plants to fire. If we wish to maintain healthy plant communities, plant dormancy and good soil moisture before burning are essential to minimize damage to plants.

In the management of shrubs, total production is of less interest to us than a maximum sustained forage that is usable by game animals. For this reason, the burning of many shrubs is necessary for the most productive ecosystem that will be of maximum benefit to mankind.

Fisher, C. E., H. T. Wiedemann, C. H. Meadors, and J. H. Brock. 1973.

Mechanical control of mesquite, p. 46-52. In, Mesquite--Growth and Development Management Econ. Control Uses. Texas A&M Univ. Res. Monogr. #1. (Prof., Asst. Prof., and Research Assoc., Texas Agr. Exp. Sta., Lubbock, and research assoc., Texas Agr. Exp. Sta., Chillicothe-Vernon; where research conducted unknown).

Mechanical methods are effective for mesquite control under a wide range of infestations and environmental conditions. The actual removal or knocking down of mesquite improves the efficiency of managing livestock, permits reseeding to more desirable forage plants and does not present hazards to susceptible crops and ornamentals.

The more intensive mechanical methods usually require a large initial capital outlay but are more effective, and benefits last longer than from use of herbicides. Retreatment is necessary in most instances to control reinfestation and plants missed by the initial operation.

Choice of mechanical methods and effectiveness are dependent on density, growth forms of mesquite and associated species of brush, previous treatment, condition of the vegetative cover of range forage plants, potential productivity of the range site, likelihood of successful reseeding, and the level of response in forage production that may be expected.

Adequate seedbed preparation for reestablishing vegetative cover resulted from root plowing. Disking, roller chopping and chaining to destroy competition from grasses and weeds and to help firm the seedbed resulted in better stands of seeded grasses.

A combination of the modified grass drill and a loose ring cultipacker and roller chopper consistently gave the best stands of grasses. Acceptable stands were obtained at low cost on root-plowed land by chaining and aerial seeding. Broadcast seeding at the time of root plowing usually gave the poorest stands of seeded grasses.

Hollingsworth, E. B., P. C. Quimby, Jr., and D. C. Jaramillo. 1973. Root plow herbicide application as a new incorporation technique. Weed Sci. 21:128-130. (Botanist, Plant Physiologist, and Agr. Research Tech., USDA-ARS, Los Lunas, N. Mex.; location where research conducted unknown).

A new method was developed for incorporating herbicides into the root zone of saltcedar (*Tamarix pentandra* Pall.) in arid, low rainfall areas. A spray pipe with five nozzles was mounted along the rear edge of a 2.44-m root plow blade. A supply line connected the spray pipe with a sprayer mounted on the plow fram. In operation, the saltcedar roots were severed at a selected depth by the blade as herbicide was sprayed simultaneously into the cut-root zone. A similar root plow with a 1.22-m blade was designed for use on small research plots.

Herbel, C. H., R. Steger, and W. L. Gould. 1974. Managing semidesert ranges in the Southwest. New Mex. State Univ. Coop. Ext. Serv. Circ. No. 456. Las Cruces, N. Mexico. 48p. (Titles unknown; research conducted primarily on the Jornada Exp. Range, New Mexico).

Hewitt, G. B., E. W. Huddleston, R. J. Lavigne, D. N. Ueckert, and J. G. Watts. 1974. Rangeland entomology. Range Science Series No. 2. Soc. Range Manage. Denver, Colorado. 127p. (Titles unknown, USDA-ARS, Texas Tech Univ., Univ. Wyoming, Texas Tech Univ., and N. Mexico State Univ., respectively; no research, a sciential report).

Wright, H. A. 1974. Range burning. J. Range Manage. 27:5-11. (Prof., Dep. Range and Wildlife Manage., Texas Tech Univ.; research conducted in the Rolling Plains of Texas).

There are many uses for prescribed burning in the management of forests, chaparral, grasslands, watersheds, and wildlife. Some of these uses have been pointed out in this paper. There are also many dangers in using fire, both in its application and in its results. To minimize

Wright 1974 (con't.)

harmful effects, fire should never be used during extended dry periods; burns should always take place when the soil is damp or wet. Moreover, the user should be an experienced professional with a thorough knowledge of ecosystems, weather, and fire behavior.

Beck, D. L., R. E. Sosebee, and E. B. Herndon. 1975. Control of honey mesquite by shredding and spraying. J. Range Manage. 28:487-490. (Grad. Research Asst., Asst. Prof., and Research Assoc., Dep. Range and Wildlife Manage., Texas Tech Univ.; research conducted near Quanah, Texas).

Simultaneous shredding and spraying of honey mesquite were studied in the Rolling Plains of Texas. Mature trees were shredded and sprayed monthly, May 1972, through October, 1972 (September was omitted). Herbicide treatments consisted of 2,4,5-T amine, 2,4,5-T ester, and Tordon 225 Mixture applied alone and in combination with naphthalene acetic acid (1, 5, 10, 50, and 10,000 ppm). Very high percentage root mortality was obtained when the trees were shredded and sprayed in May, with somewhat lower percentages obtained from treatments applied in June and October. Root mortality obtained from treatments applied in July and August was generally lower than that obtained from treatments applied any month of the study exceeded the results one could expect from either shredding or spraying applied alone during a comparable period. Tordon 225 Mixture was consistently more effective in controlling shredded mesquite. Therefore, shredding accompanied by a simultaneous herbicide application has potential in control programs.

Durham, G. P., C. J. Scifres, and J. L. Mietz. 1975. Comparison of herbicides and chaining for control of South Texas Mixed Brush, p. 18-19. In, Range Resources Research 1971-74. Texas Agr. Exp. Sta. College Station, Texas. Consolidated Prog. Rep. 3341. (Research Asst., Assoc. Prof., Research Assoc., Texas Agr. Exp. Sta.; research conducted near Raymondville, Texas).

One of the primary factors limiting beef production in deep South Texas is the dense stands of brush. Typical South Texas "brush" country consists of dense stands of woody plants stratified into an overstory of honey mesquite and huisache with an almost impenetrable understory of plants including spiny hackberry, lime pricklyash and pricklypear.

Durham et al. 1975 (con't.)

Several herbicides and herbicide combinations at 1 lb/acre were compared with chaining one way; chaining two ways; and chaining two ways, raking, stacking, and burning the debris on the El Sauz Ranch, 15 miles east of Raymondville, Texas. Herbicides were aerially applied on May 10, 1973, and mechanical plots were installed on September 6, 1973.

At 1 year after application, all herbicide combinations had resulted in excellent control of honey mesquite and pricklypear. The combination of 2,4,5-T + dicamba (1:1) increased control of spiny hackberry by 15% compared with 2,4,5-T alone. However, 2,4,5-T + picloram (1:1) resulted in the most effective control of all the woody species. Spiny hackberry and lime pricklyash, which were resistant to the other herbicide combinations, were effectively controlled by 2,4,5-T + picloram.

The mechanical treatments were evaluated on the basis of frequency, density and cover for each woody species on August 1, 1974. All three relative terms were combined to form an importance value index for each species in each treatment.

Each successive mechanical treatment improved control of honey mesquite, huisache and lime pricklyash but was not effective in controlling smaller many-stemmed plants such as spiny hackberry. Through the removal of competition from the other brush species, spiny hackberry will probably form the primary brush problem following mechanical treatment of such sites.

Integration of mechanical treatments with application of herbicides possibly could more effectively control a broader spectrum of the brush species and extend the length of control compared with that of the methods used singly.

Kothmann, M. M. and C. J. Scifres. 1975. Influence of a wildfire following aerial spraying on honey mesquite regrowth in the Rolling Plains, p. 25-26. In, Rangeland Resources Research. Texas Agr. Exp. Sta., Consolidated Prog, Rep. 3341. Texas A&M Univ., College Station, Texas. (Assoc. Profs., Texas Agr. Exp. Sta., College Station; observations made near Thockmorton, Texas).

The Texas Experimental Ranch in the Rolling Plains near Throckmorton was sprayed with 1 lb/acre of 2,4,5-T in a diesel oil:water emulsion during early June 1972. In the winter of 1973, an accidental fire occurred on the ranch which, due to high wind velocities and dry standing fuel, reached wildfire proportions. The sprayed honey mesquite subjected to the wildfire was compared in 1974 with that on the same

Kothmann and Scifres 1975 (con't.)

range sites not exposed to the burn. The number of green sprouts plant was reduced from 16 for the sprayed only to 13 for the sprayed and burned. There was a general trend toward reduced vigor of honey mesquite resprouts in the burned compared with the unburned areas.

Plants in the unburned pastures had regrowth approximately 24 inches tall--about twice that of plants in areas which had been burned. The canopy area of regrowth was reduced by about 60% by the burn. Lotebush in the sprayed areas was completely defoliated the year following treatment. They had begun to refoliate just prior to the wildfire. The wildfire removed most of the above-ground lotebush growth so that sprout height was reduced by more than 85% and canopy area by more than 75%. Although the wildfire did not occur under the most desirable conditions for burning, results indicate that fire following aerial spraying may have desirable effects in retarding growth of sprayed woody plants.

Scifres, C. J. and G. P. Durham. 1975. Preliminary results from aerial spraying followed by burning for control of mixed brush, p. 27. In, Rangeland Resources Research. Texas Agr. Exp. Sta. Consolidated Prog. Rep. 3341. Texas A&M Univ., College Station, Texas. (Assoc. Prof., and Grad. Research Asst., Texas Agr. Exp. Sta., College Station, Texas; research conducted in south Texas).

Prescribed burning treatments were installed in February 1974 on areas treated 10 months previously with commercial, aerial applicaton of 1 lb/acre of 2,4,5-T + picloram (1:1) and on previously untreated areas. All burns were installed as headfires. The fire plan included back firing where necessary and the use of natural structures or ranch roads as fire guards.

More effective burns resulted on sites which were predominantly clay and supporting dense stands of spike dropseed, which provided fuel, than on lighter soils. Much of the small, woody growth and debris on the ground was removed by the burn. The previously applied herbicides had controlled about 90% of the pricklypear. Many of the remaining pricklypear plants were quickly sought out by cattle immediately following the burn.

Preliminary data indicate that the burn following the spray did not decrease basal sprouting of honey mesquite surviving the sprays. About 12% of the large trees (trunk diameter exceeding 6 inches) were burned down. In many cases, mats of longtom developed over the remaining stumps by 6 months after the burn.

Scifres and Durham 1975 (con't.)

The burn apparently had a more detrimental effect on the smaller, many-stemmed species such as spiny hackberry and live pricklyash than on honey mesquite. No spiny hackberry plants were completely controlled in the sprayed area, whereas about 10% were controlled by the burn following the spray. The percentage of the spiny hackberry with tops killed but which were resprouting from the trunk bases increased by 57%. Lime pricklyash, the most resistant species to the herbicide spray, was also damaged further by the burn. In areas sprayed only, no lime pricklyash were killed. Following the burn, more than 10% of the lime pricklyash plants were controlled, and about 75% were defoliated in excess of 50%.

Wiedmann, H. T. and B. T. Cross. 1975. Low-energy grubbing for economical control of small tress, p. 35-36. In, Rangeland Resources Research 1971-74. Texas Agr. Exp. Sta. Consolidated Prog. Rep. 3341. 70p. (Asst. Prof. and Research Tech., Texas Agr. Exp. Sta.; research conducted at various locations in the Rolling Plains of Texas).

Ranchmen need a low-cost method of controlling honey mesquite and juniper which are reinfesting previously cleared pastures. Grubbing, the uprooting of the tree by severing roots with a sharp blade below the bud zone, has been an effective control method. The use of large, 100-plus horsepower crawler tractors, which has been popular for sparse to moderate densities of large trees, has not been economical for grubbing stands of small trees.

A small, 65-horsepower, shift-on-the-go, crawler tractor was adapted for grubbing by attaching a sharp U-shaped blade to the front C-frame for root cutting at depths of 6 to 12 inches. A hydraulic attachment to vary the cutting-blade slope was designed for improved soil penetration and tree cutting capacity. An operational cost of $15/hr was assigned to the machine based on charges by conservation contractors for equivalent tractors. Costs averaged between $1 and $5/acre in sparse infestations of 35 to 100 plants/acre. The newly designed hydraulic attachment has increased tree-cutting capacity by 33%.

The low-energy tractor averaged 11.1 acres/hr while grubbing 35 of the 46 trees/acre on a 1,400-acre site near Guthrie. Honey mesquite trees, 1 to 6 ft tall, had reinfested following land grubbing in the 1940's and oiling in the 1950's. Of the 11 trees/acre missed, most were less than 18 inches tall and not easily seen by the operator. Averages of 14 and 7.7 acres/hr were recorded for two different operators during the 1,400-acre grubbing test, exemplifying the importance of a good operator.

Wiedmann and Cross 1975 (con't.)

The hydraulic attachment uprooted honey mesquite trees with an average root diameter of 4 inches compared with an average diameter of 4 inches compared with an average diameter of 3 inches for the standard grubber. Honey mesquite, 1 to 10 ft tall, on the 480-acre test site, had also reinfested following hand grubbing in the 1940's and oiling in the 1950's. The average rate for all treatments was 13.5 acres/hr in the 35-tree/acre infestation.

A 103-acre juniper infestation near Stephenville was divided into 19 different classifications, with tree size from 1 to 12 ft tall and densities from 27 to 978 trees/acre. An average grubbing rate of 2.6 acres/hr (7 trees/min) at a contract cost of $5.82/acre was maintained in the 164-tree/acre infestation. In a typical sparse infestation of 57 trees/acre, 7 acres/hr (6.7 trees/min) were grubbed at a $2.14/acre cost. Grubbing was especially easy because plants were in a shallow top soil underlain by a hard limestone layer.

The major difference between the low-energy tractor and a 120-horsepower crawler tractor, in direct competition, in open stands of 10 trees/acre at 10 years following root plowing, was cost/hr-- $25/hr for high-energy versus $15/hr for low-energy grubbing. Contract costs averaged $1.15/acre for high energy and $0.60/acre for low-energy grubbing.

Low-energy grubbing is suited for the control of honey mesquite, juniper and associated brush species reinfesting pastures in sparse stands following root plowing, cleanup following large-tree grubbing or regrowth following aerial spraying and chaining where original stumps are fairly small.

Bovey, R. W., T. O. Flynt, R. E. Meyer, J. R. Baur, and T. E. Riley. 1976. Subsurface herbicide applicator for brush control. J. Range Manage. 29:338-341. (Research Agronomist, Agr. Research Tech., Plant Physiologist, Plant Physiologist, and Agr. Research Tech., USDA-ARS, College Station, Texas; research conducted near College Station).

A tractor-drawn machine was designed to apply soil-active herbicides subsurface to experimental brush control plots. The applicator was constructed with a large coulter, 32 inches in diameter, to penetrate soil to a depth of 0 to 8 inches and to cut through woody vegetation. An injector-knife immediately behind the coulter supported a spray nozzle to apply herbicide into the bottom of the slice made by the coulter. The injector applies herbicides in continuous narrow bands spaced on 6-inch centers at 3- to 6-ft intervals and requires low energy input to operate. Spacing of herbicide bands depends upon type and size of brush being treated.

Wright, H. A., S. C. Bunting, and L. F. Neuenschwander. 1976. Effect of fire on honey mesquite. J. Range Manage. 29:467-471. (Prof., Research Assoc. and Grad. Research Asst., Dep. Range and Wildlife Manage., Texas Tech Univ., Lubbock; research conducted in the Rolling and High Plains of Texas).

Based on this research and other work that has been reported, honey mesquite is very difficult to kill with fire on the High Plains and along river bottoms in the Rolling Plains. On upland sites in the Rolling Plains, 27% of the mesquite trees were killed following single fires. Using repeated fires on upland sites at 5 to 10 year intervals, the potential exists to kill 50% of the older mesquite trees. Seedlings of honey mesquite were easy to kill with moderate fires until they reached 1.5 years of age, severely harmed at 2.5 years of age, and very tolerant of intense fires after 3.5 years of age.

Ward, C. R., C. W. O'Brien, L. B. O'Brien, D. E. Foster, and E. W. Huddleston. 1977. Annotated checklist of new world insects associated with *Prosopis* (mesquite). U.S. Dep. Agr. Tech. Bull. Agr. Res. Serv. No. 1557. Washington, D. C. 115p. (Credentials unknown).

The insects that have been collected on or reared from *Prosopis* in the New World are listed alphabetically by orders and families. Specific host records, ecological notes, alternate hosts, synonyms, distribution data, and information sources are given. The insects are indexed by host plant and insect species name.

Boyd, W. E., R. E. Sosebee, and E. B. Herndon. 1978. Shredding and spraying honey mesquite. J. Range Manage. 31:230-233. (Grad. Research Asst., Assoc. Prof., and Research Assoc., Dep. Range and Wildlife Manage., Texas Tech Univ.; research conducted near Quanah, Texas).

Shredding and spraying honey mesquite is an effective method of control. Overall, the highest percent root mortalities were obtained from treatments applied in May, but shredding and spraying were effective when applied during other months of the year, even during the fall and winter. Root mortalities obtained from aqueous solutions of either 2,4,5-T amine or picloram plus 2,4,5-T during the year were dependent upon water content and temperature in the upper 15 cm of the soil (2,4,5-T, R=0.88;

Boyd et al. 1978 (con't.)

picloram plus 2,4,5-T, R=0.82). Average root mortalities for all months were consistently the greatest from picloram plus 2,4,5-T (57%), followed by dicamba (34%) and dicamba plus 2,4,5-T (31%). Root mortalities obtained from 2,4,5-T amine (26%) and 2,4,5-T ester (25%) were the lowest obtained in the study.

Jennings, J. . Fire! To help control brush. The Cattleman.

(Credentials unknown; report research conducted in the Rolling Plains of Texas).

IV. Alternative Methods of Control
A. Effectiveness

SUMMARY AND CONCLUSIONS

Methods of mesquite control alternative to spraying can generally be broken into 3 or 4 major categories: 1) mechanical, including hand methods; 2) biological; 3) fire; and 4) application of dry herbicides.

Mechanical

One of the oldest mechanical treatments used to control mesquite is hand grubbing. Hand grubbing was used extensively in the 1940's and 1950's when labor was available and inexpensive. Countless acres were hand grubbed and the mesquite was very effectively controlled. A major precaution that one must observe in hand grubbing mesquite is that the plant must be severed below the basal bud region (located just below the soil surface) to prevent any resprouting (Herbel et al., 1958). Hand grubbing is nearly always limited to situations where mesquite infestations are light and trees are small. Herbel et al. (1958) found that mesquite densities exceeding 150 trees/acre or had an aerial crown diameter greater than 30 inches required too much time to be considered a feasible method of control. Optimal mesquite densities would not exceed 50 trees/acre (Anon., 1965).

Power grubbing dates back to the mid-1930's (Fisher et al., 1973), but was not successfully developed until the late 1960's. Power grubbing can be used effectively to control extensive stands of thin, open stands of mesquite or to "clean up" following aerial spraying or other methods of mechanical control (Fisher et al., 1973). Most of the power grubbers used during the developing years included a "stinger" blade mounted on the dozer blade of a crawler-type tractor. However, Catepillar developed the traxcavator in which the grubber was mounted on a front-end loader with individual hydraulic controls (Churchill and Schuster, 1971). Subsequently, a low-energy grubber was developed by the Texas Agricultural Experiment Station (Wiedemann and Cross, 1975). The low-energy grubber averages between 2 and 12 acres/hr depending upon the density and size of the trees.

Chaining is sometimes used to control mesquite. It is most effective on large, single-stemmed trees occurring in moderate to dense stands (Fisher et al., 1973). Effectiveness is increased if the operation is performed in opposite directions (often referred to as "double chaining"), when the soil is wet so the trees will be uprooted. If the plants are broken off and not uprooted, the mesquite problem may be magnified because of increased basal sprouting. Chaining is not effective on small, multiple-stemmed mesquite plants (shrubs) because the plants only bend under the influence of the chain. The plants are neither broken off nor uprooted.

Chaining is often used effectively in combination with aerial spraying. Once the trees have been controlled chemically, chaining is often used to remove the old dead stems left standing. It is sometimes used in combination with root plowing for seedbed preparation (Brock et al., 1970).

Perhaps the most common mechanical method of mesquite control is root plowing. The root plow, a large V-shaped blade mounted behind a crawler-type tractor, was developed for clearing dense stands of mesquite. Root plowing is pulled about 10 to 16 inches below the soil surface to severe all mesquite roots below the basal bud zone. Most of the associated vegetation is destroyed at the same time mesquite is controlled (Fisher et al., 1973). Root plowing is usually quite effective in controlling mesquite (killing 80 to 90% of the trees present), but it must be used with discretion, especially in climatic regimes where revegetation is difficult.

Reseeding must nearly always accompany root plowing. Herbel et al. (1974) discussed mesquite control in the southwestern U.S. in which a root plow is followed by a drill through which the area is reseeded and that is followed by a conveyor that piles the brush over the reseeded area to reduce soil temperatures. They have demonstrated phenomenal success with the above mentioned equipment, however, the costs involved would be a limiting factor. Areas suitable for root plowing, generally are capable of producing cash crops. A procedure used by some of the larger ranches in South Texas includes root plowing followed by planting the area root plowed with a cash crop for 2 to 3 years to recuperate some (or most) of the cost of root plowing. After 2 to 3 years the area is reseeded to native or improved grasses. Farming the root plowed area for 2 to 3 years provides the additional benefit of seedbed preparation.

Root plowing can be used in combination with chemical treatments of mesquite (Hollingsworth et al., 1973; and Bovey et al., 1976). The herbicides are placed below the soil surface in the root zone of the plants to be controlled. Either liquid or dry herbicides may be incorporated in this system.

Shredding mesquite has not been recognized as a viable method of control. It has been used occasionally for "maintenance" control on small acreages. Shredding alone tends to produce a pruning effect on mesquite that initiates basal sprouting often resulting in a greater problem than prior to shredding (Carpenter, 1970). However, a shredder has been developed and modified (although not presently available commercially) that is capable of spraying the stumps of shredded trees simultaneously with the shredding operation. This method of control has a great deal of potential for use in some areas infested with mesquite. Beck et al. (1975) and Boyd et al. (1978) have shown that shredding and spraying may be done during any season of the year (as long as water in the upper 6 inches of soil is adequate). The highest degrees of success was obtained when the stumps were sprayed with picloram plus 2,4,5-T. When soil water was adequate, more than 50% and often 70% more of the trees were controlled.

Circumstantial evidence seems to support shredding mesquite, without applying herbicides, when the soil is dry. Although many of the trees are not killed, they are sufficiently suppressed so that regrowth is slow and not as abundant as when soil water content is high. However, if shredding is initiated without use of accompanying herbicides, one is committed to regularly shredding or eventual use of herbicides to control mesquite regrowth.

Biological

Biological control of mesquite has been studied only to a limited extent, but has been reported to be feasible (Hewitt et al., 1974). Numerous insects are associated with mesquite (Ward et al., 1977), but few if any, are capable of controlling mesquite to the degree desired. Most insects that are adapted to native host plants have evolved a co-existence that allows mutual benefit of both organisms, or at least no detrimental effect of one on the other. Therefore, achieving biological control of mesquite with insects adapted to it and part of its natural environment is not eminent.

There are insects that inflict a certain amount of control on the plants but they do not kill their host. Ueckert et al. (1971) found that the twig girdler damages the plant in the process of laying eggs in the twigs. The twigs acropetalous to the girdle die and eventually fall from the tree. This keeps the shrub pruned, but does not kill it.

Fire

Fire is a management tool that has an undesirable connotation and is dreaded by many people. It has been studied several years in the Southwestern U.S. for use on rangelands (Humphrey, 1949; Blydenstein, 1957; and Cable, 1961) but the conditions under which fires could be prescribed have not been known until recently. Generally, range or forest fires are ignited during the periods when burning would be least practical as a management tool.

Wright (1974) summarized range burning and illustrated its effect on rangeland vegetation. Generally, live mesquite trees are difficult to kill by burning (Wright, 1971). However, burning with the proper amount of fuel and climatic conditions effectively control mesquite (Jennings,). On upland sites in the Rolling Plains of Texas, 27% of the mesquite trees were killed with a single fire (Wright et al., 1976). Seedlings or very young trees may escape damage from fire depending upon their age (Cable, 1961; and Wright et al., 1976). Mesquite growing on the High Plains and along the rivers in the Rolling Plains of Texas is also tolerant to fire (Wright et al., 1976). Fire following aerial spraying may (Kothmann and Scifres, 1975) or may not (Scifres and Durham, 1975) decrease sprouting among the sprayed trees.

Use of dry herbicides.

Although dry herbicides are not sprayed on mesquite, they are often aerially applied. They have been discussed in Section I.

IV. Alternative Methods of Control
B. Economic Feasibility

Fox, A. S., R. P. Jenkins, P. A. Andrilenas, J. T. Holstun, Jr., and D. L. Klingman. 1970. Restricting the use of phenoxy herbicides--cost to farmers. U.S. Dep. Agr., Agr. Econ. Rep. No. 194. U.S. Gov. Printing Office. Washington, D.C. 32p. (First three authors, Agr. Econ., USDA-ARS and last two authors, Agron., USDA-ARS; summary from entire U.S.).

Assuming the current levels of farm production are to be maintained, restricting the farm use of phenoxy herbicides would increase U.S. farmers direct production costs about $290 million. In addition, about 20 million more hr of family labor would be used.

Net reductions in farm income would total $107 million for corn, $51 million for wheat, $8 million for rice, $28 million for other small grain, $11 million for sorghum, $33 million for pasture, $36 million for rangeland, and $16 million for other crops on which the phenoxys were used in 1966. The estimates were determined for each of the above crops by partial budgeting using cross-sectional data from the ERS Pesticide and General Farm Survey, 1966; Agricultural Statistics 1968; and from Agricultural Research Service weed scientists.

Fox, A. S., R. P. Jenkins, J. T. Holstun, Jr., and D. S. Klingman. 1971. Restricting the use of 2,4,5-T: costs to domestic users. U.S. Dep. Agr., Agr. Econ. Rep. No. 199. U.S. Gov. Printing Office. Washington, D.C. (First two authors, Agr. Econ., USDA-ARS, and last two authors Agron. , USDA-ARS; summary from entire U.S.).

About 3.4 million acres of farmland and 4.5 million acres of nonfarmland were treated with an estimated 8.9 million lb of the phenoxy herbicide 2,4,5-T in 1969. If 2,4,5-T were restricted, the economic costs to domestic users would have been $52 million in 1969, providing all other herbicides could still be used. However, costs would have increased to $172 million if other phenoxy herbicides were also prohibited. Additional costs to replace 2,4,5-T, if other phenoxys could have been used as alternatives, were estimated at $32 million for farmers and $20 million for other domestic users (public utility companies, Government agencies, homeowners, recreation, and timber

Fox et al. 1971 (con't.)

industries). Without other phenoxys, additional costs would have increased to $44 million for farmers and to $128 million for nonfarm users. For farmers, the major land areas affected would be pasture and rangeland; for nonfarm users, rights-of-way maintenance would be most affected.

IV. Alternative Methods of Control
B. Economic Feasibility

SUMMARY AND CONCLUSIONS

The economic feasibility of using alternative methods to chemical control of mesquite is dictated by the financial status and objectives of each individual landowner and/or manager. It is also dictated by reasons other than economics, e.g. site, location, associated species, and proximity to cultivated crops. All things being equal, chemical control of mesquite is cheaper than mechanical control. Fire is inexpensive, but only trained individuals should burn large areas. Biological control is not at all practical at the present time, mainly because we don't know the ecological relationships of the insects that feed on mesquite.

If one pursued mechanical control of mesquite in areas where it would be appropriate, they should include more than the method of control in their program. Great Plains Conservation Programs that have been most successful in revegetating an area following mechanical control included rootplowing and rollerchopping or raking (to prepare an adequate seed bed) and reseeding. To assure a success, both vegetatively and economically, one should either farm a cash crop for a couple of years on the rootplowed area or reseed improved, introduced grasses and plan to harvest the seed for sale the first year or two. This procedure prepares an adequate seedbed and substantially improves one's chances of getting a reasonable stand of grass on the rangeland. These costs can be \$50 to >\$200/acre, depending upon the density of mesquite, location, and number of practices includes. Not every situation lends itself to mechanical control. Mechanical control of most mesquite infested rangeland in the Southwest would be more detrimental than beneficial, because of lack of precipitation to insure a successful reseeding program.

Cost to aerially spray mesquite is about $4 to $12/acre, depending upon herbicide and rate used. However, this treatment usually must be repeated every 8 to 10 years.

Another way of assess the feasibility of using some method of mesquite besides chemical, is to evaluate the impact of removing herbicides, particularly 2,4,5-T on both the farmers-ranchers and the consumers (Fox et al., 1970; Fox et al., 1971). Fox et al (1970) pointed out weeds that escape control, often become the predominant species. Furthermore they indicate that removal of an essential component of weed control, such as the phenoxy herbicides, without replacement with a satisfactory alternative, can make the entire system ineffective. Fox et al. (1970) summarized the impact of banning phenoxy herbicides on pasture and rangeland as follows: "Stopping the use of phenoxy herbicides would add about $290 million to farm costs. When phenoxy herbicides are used to control weeds on 62.5 million acres, costs per acre for these herbicides and their application are $1.64/acre. Alternative methods that could replace phenoxy herbicides on these acres would add $4.64/acre. This would increase the total cost to $6.28/acre--nearly four times that of the phenoxy herbicides. The increase in cost is about 1% of the farm value of all crops or 5% of the value of crops from the treated acres.

The herbicides substituted for phenoxys on 38.7 million acres would increase farm costs for materials and application $60.7 million above those for phenoxys. The cost of substitute herbicides and application ($163 million) would be $4.22/acre for nearly 39 million acres treated. Corn production would account for 75% of the increase in the cost of purchasing and applying substitute herbicides.

Over 5.7 million additional acres of cropland, not including rice, would be needed to maintain production and offset yield losses. Additional variable costs of $90 million would be incurred in adding these acres. The average variable costs on the additional acres was $15.79/acre added. About 90% of the added acres would be needed to maintain the production of wheat and small grains.

Range renovation and seeding, mowing to control weeds, and other cultural practices on crops other than rice would add $131 million to farm costs. These cultural practices would be needed on 30.6 million acres at an average cost of $4.28/acre. Pasture and rangeland would account for 66% of the added costs of cultural practices.

Lowered quality of rice would add another $2 million to the cost of restricting the use of phenoxy herbicides. Also, net additional costs for cultural practices on rice and the added variable costs of substituting rice for soybeans add $6 million to costs.

The total additional costs for maintaining production would be distributed among crops as follows: corn, 37%; wheat, 17%; other small grains, 10%; sorghum, 4%; rice, 3%; other crops, 6%; pasture, 11%; and rangeland, 12%.

In addition to the costs resulting from the prohibition of phenoxy herbicides, farm operators and their families would need to provide nearly 20 million hr of additional labor to maintain current production and marketing.

☆ U. S. GOVERNMENT PRINTING OFFICE 1980 - 678-317/403 Reg. 8